MEDICAL SCIENCE PUBLICATION NO. 4

RECENT ADVANCES IN MEDICINE AND SURGERY

(19-30 APRIL 1954)

BASED ON PROFESSIONAL MEDICAL EXPERIENCES IN JAPAN AND KOREA 1950-1953

ARMY MEDICAL SERVICE GRADUATE SCHOOL
WALTER REED ARMY MEDICAL CENTER
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VOLUME I

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WALTER REED ARMY MEDICAL CENTER
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PREFACE

These volumes represent complete notes of a course entitled Recent Advances in Medicine and Surgery conducted by the Army Medical Service Graduate School, 19–30 April 1954. The title is a slight misnomer inasmuch as it was intended by those responsible for the course's design that it reflect primarily the professional experiences, problems encountered and lessons learned by the Army Medical Service during the Korean war. To this end the faculty was selected from individuals "who were there," who met and successfully coped with the actual problems and, as a result, could speak with the authority of personal and intimate knowledge of the subject. The student body was drawn from mature clinicians so that a critical discussion of papers could be had prior to final editing for this volume. The opinions thus collected are presented neither as infallible nor incapable of further improvement. They are, though, considered to be the best thinking on the subject at this time and in a literal sense, constitute a history of the professional and clinical activities of the Army Medical Service in Korea.

It is hoped that the timely publication of these lessons and their general distribution to Reserve training groups, libraries and medical schools, will help to better prepare the next doctors who are called on to treat mass casualties—whether they be as a result of military or civilian disasters.

To the many who participated and gave so unstintingly of time and energies I wish to say—thank you. Sole credit can never be attributed to any single individual for a group type of enterprise but it is desired to make a matter of record the contributions of Colonel William S. Stone, Commandant of the Army Medical Service Graduate School when this course was held. It was he who recognized the need for such a review and who in addition contributed the greatest single share of all the necessary planning and execution from inception to end.

FRANK L. BAUER,
Lieutenant Colonel, MC.

WASHINGTON, D. C., *2 August 1954.*

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SOME GENERAL CONSIDERATIONS OF HOMEOSTATIC AND ADAPTIVE MECHANISMS TO STRESS IN EFFECT PRIOR TO WOUNDING*

Stanley H. Eldred, M. D.

It has been repeatedly noted in World War II, Korea, and in civilian catastrophes that individuals respond to similarly painful situations with unequal degrees of effectiveness. This matter of individual differences has been approached from a variety of points of view, i. e., hereditary-constitutional factors, environmental factors (such as the personal emotional development of the subject in terms of his relationships with significant other people in his past), cultural-familial patterns in which he grew up, motivation for combat, etc. Among the environmental factors which seem to be of considerable importance are those in existence shortly preceding wounding. Not only are these factors of considerable importance, but they seem to be factors which, if we knew enough, would permit of some control. That is, in practical terms, research in this area may ultimately provide us with the knowledge necessary to minimize wounding and to maximize the effective destructive force upon the enemy.

The purpose of this paper is not to present a major contribution to our knowledge, but rather to bring together several incomplete but nonetheless convincing observations about conditions existing prior to wounding, which seem to affect the manner in which the trauma is handled.

Many of you with battalion aid station experience during combat have noticed that different men react differently to similar wounds. One source of evidence comes from observations of reactions to blast effects from grenades and mortar shells. One soldier will react so that he is diagnosed as having concussion of the brain, lung, stomach, or bowels. Another soldier exposed to the same blast will continue to go about his business with or without somatic complaints. If the trauma is equal or only approximately equal, the question arises, why does one man continue aggressive action and the other become immobilized?

*Presented 19 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

This problem became of interest to the speaker about a year ago while conducting exploratory interviews with company commanders who had been wounded in Korea. With 26 of these officers the interviews provided some data about stresses extant prior to wounding and the individual's reaction to his wound. While not of statistical import, because of the absence of controls and because of the limited number of cases, we were, nonetheless, impressed by the fact that with five exceptions the behavioral response to ultimately incapacitating wounds fell about equally into two large categories, i. e., those who from the moment of impact were immobilized for further action, and those who continued effective aggressive action for a significant period of time after impact. In order that I might demonstrate the complexity of this problem, permit me to give some examples from these interviews.

1. Second Lieutenant R. took command of a company for a period of 2 days after it had been reduced, because of combat casualties, to 3 officers and 56 men. While under attack he received mortar wounds to left leg, ultimately resulting in amputation. Several days of sleeplessness, cold weather, and some 3,000 rounds of shells in previous 24 hours in the area preceded his injury. He regained consciousness a few minutes after injury, turned his command over to another officer, and was shortly thereafter sedated with morphine and evacuated. Careful psychiatric interviewing revealed no evidence of a feeling of guilt about leaving his unit. He was only grateful that he had been wounded rather than killed.

2. Captain A. took over a problem company 6 months prior to injury and was successful in making it a more effective unit. He was wounded by a direct hit on his command post. Two sergeants were killed. His right arm and leg were fractured. After regaining consciousness he was quickly evacuated. He had a great sense of guilt about carelessness in placing his tent in an exposed position, and felt responsible for the deaths of his sergeants.

3. Captain S. was one of six men remaining in an outpost. Six of eight bunkers had been overrun when he had called for artillery fire on position. He was wounded by a grenade, sustaining multiple fractures of the left arm and leg. He continued to throw grenades until too weak, then assisted an old sergeant with a machine gun until reinforcements arrived, at which point he went into deep shock. He remembers being very angry at being wounded.

4. Captain J., tank company commander, had to go from A to B defensively through two ravines. A major, a stranger to the captain, ordered him to split his unit into two forces. The captain's force was quickly pinned down in the valley. After 10 minutes of immobili-

zation he opened the turret, got out, picked up the wounded, and ordered his riflemen out of ditches. He continued going up the valley standing up in the turret of his tank, so his men could see him. A mortar shell hit his tank, destroying both his hands and fracturing his face and arms. He was knocked unconscious by the blast, but upon coming to his first question was to ask who else had been hurt. He then resumed radio command until the objective was reached, at which point he went into shock. There was no sense of guilt about leaving his company. He volunteered the statement that his anger at being ordered to split his unit against his own better judgment made him more reckless.

I have only hinted at the psychological factors which are obvious in their presence and complex in their operation. That which I would like to underline at this point, however, is the fact that these statements indicate that there are probably physiological differences which are concomitant and concurrent with psychological differences.

Inasmuch as we have little direct evidence of the physiology involved in these two different types of reaction to wounding, further explanations can be sought by drawing upon available experimental data. Such experimental data include the work of Funkenstein, *et al.*, at Harvard, on the "Experimental Evocation of Stress," in which experimental psychological stress is correlated with certain physiological responses, as measured by ballistocardiograph patterns, blood pressure and pulse rate. In their 70 subjects, two major responses, analogous to the two major types of responses to combat wounds, were noted: (1) those which were characterized by anger being directed outward, and (2) those characterized by anger directed inward toward the self. These two physiological patterns correspond to those which can be obtained by injections of norepinephrine and epinephrine respectively.

Captain Morton F. Reiser, of the Neuropsychiatry Division of the Army Medical Service Graduate School, has recently contributed some significant measurements tending to refine and extend Dr. Funkenstein's thesis. Correlating simultaneous recordings of the ballistocardiograph, EKG, pulse rate and blood pressure with tape recordings of interviews with young healthy males, he has demonstrated an "epinephrine" physiological pattern (high cardiac output, rapid pulse rate, wide pulse pressure, and little change in mean blood pressure indicative of decreased peripheral resistance) in those subjects in whom anger was not expressed during the stressful interview. In those subjects expressing open anger, there was demonstrated a norepinephrine pattern of physiological response, namely, no change in cardiac output and pulse rate, and a rise in mean blood pressure, indicating a rise in peripheral resistance.

I must at this point ask for forbearance from the physiologists among you for this presumptuous oversimplification of their specialty. However, I do so only to suggest the possibility of a method of closer collaborative effort between physiologist and psychiatrist. Specifically, it would appear on an *a priori* basis that the norepinephrine type of physiological response to stress, with its specific psychological component (outward directed anger), is a more effective pattern of behavior for combat purposes than the epinephrine type of response. To this end it would appear profitable to explore the possibilities of delineating those psychological factors which can be manipulated to favor the norepinephrine type of psycho-physiological response to stress. It has been demonstrated that any given individual is capable of both types of physiological response, and it is to be noted that immediate environmental factors influence the manner in which the subject responds to the experimental stress. That is, when the interviews in Captain Reiser's study were conducted by an educated, well-trained enlisted man, there was a freer expression of anger outward by the subjects. The responses obtained to similar interviews conducted by a captain in the Medical Corps contained very few outward expressions of anger, and correspondingly fewer norepinephrine-like patterns were obtained with the physiological measurements. This is not evidence against the existence of individual tendencies to respond more often or more strongly in one direction or another. The multiplicity of psychological factors involved in even this simplified laboratory situation indicates the need for further study to determine the more crucial psychological factors.

There are few published reports of direct psychiatric observation of subjects at the moment of wounding. I know of none dealing specifically with this problem of different types of reaction to acute injury, although I have by no means covered the extensive literature in this general area. We can, however, refer to some of the systematic observations upon convalescent combat cases and see if these findings elucidate the retrospective reports from the wounded about their reactions to being wounded. In February 1954, Noble, Roudebush and Price published in the *American Journal of Psychiatry* a report of their study of 53 amputees on the orthopedic wards of the U. S. Naval Hospital in Bethesda and of Walter Reed Army Medical Center. One aspect of their data which may be pertinent to the study of how acute wounds are handled by the wounded pertains to the various defenses employed by the amputees to avoid anxieties over separation, loss of body parts, aggressive feelings and passivity. These defenses included *denial* of loss in a variety of ways, *displacement* of feelings from the genital organs to the amputated extremity, *projection* of their own

attitudes about amputation onto others, and *identification* with a significant other person who had a similar difficulty.

Dr. David A. Hamburg, in his study of severely burned patients, has emphasized the role of *denial* of injury in maintaining homeostatis. Dr. E. Weinstein has commented on the mechanisms of *denial* of injury and *projection* of anxiety as means of maintaining a modicum of personal identity in the face of severe brain damage. Is it possible that similar mechanisms are employed to handle anxieties inherent in the acute stage of wounding? If our retrospective reports bear any resemblance to that which actually happened, it is clear that *denial* of injury is very common. It takes place in at least three ways, depending only in part upon the severity and location of the trauma. Many tearing flesh and muscle wounds, as well as fractures of arms, hands, ribs, face and skull, are "discovered" by the recipient only after there is a decrease in the intensity of the combat. The trauma was not admitted into awareness while the awareness was focused elsewhere. Another way in which *denial* functions is to minimize the severity or to put off evaluating the severity of a wound as long as aggressive action is necessary and to go on "as if I weren't hurt." A third way that has been reported is to take what first aid measures are possible and then "forget about it until later." *Mechanisms of projection* are to be seen in the rather primitive half-truth of blaming the enemy for one's injury. This is a lot easier to do than to objectively evaluate one's own possible role in getting wounded, e. g., reckless, unnecessary exposure to fire. *Identification* with others in the combat unit seems to be a factor in maintaining homeostasis, e. g., Captain J. in example No. 4 above.

While these mental mechanisms are frequently elicited in interviews with those who have continued aggressive action after being wounded, our interview data would suggest that there are at least two common denominators in this phenomenon. These seem to be: (1) a ragelike reaction directed toward the enemy, and (2) the fact that the situation is appropriate for immediate aggressive action against the enemy.

It is physiologically plausible, then, that these aforementioned psychological concomitants make it possible for some individuals to postpone or avoid the advent of traumatic shock. In those who have not demonstrated such post-traumatic aggressiveness, and in whom traumatic shock has set in rapidly, we have not obtained evidence in the interviews which suggests a rage reaction to being wounded. This would possibly be analogous to the epinephrine type of response with peripheral vasodilatation and decreased mean blood pressure.

To attempt to delineate those stresses in operation prior to wounding which tend to make for effective aggressive adaptations is beyond the

scope of this paper. This could, as a matter of fact, be one of the goals of this symposium and of many symposiums to come.

That with which I would like to conclude, however, is to underline the fact that given the wide range of individual precombat adaptations, there is highly suggestive psychological and physiological evidence of the existence of important factors in the immediate combat situation which affect the aggressive potential of the individual and, hence, of the unit. It is in this area that further study is indicated.

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FATIGUE AND METABOLIC DEFICIT

A STUDY OF THE COMBAT AND INJURED SOLDIER*

JOHN M. HOWARD, M. D.

These observations were made on the Eastern Front in Korea during the first half of 1952 and to a lesser extent throughout the succeeding year. January 1952 was a time when the front lines had begun to stabilize. There was complete uncertainty among the troops as to the tactical moves to be made by our forces as well as the forces of the enemy. Fighting was beginning to be limited to probing actions, patrols, and exchange of mortar and heavy artillery fire. The front lines were strung out across a chain of mountain tops and men had, at this time, reasonable protection from the cold.

Under these conditions, fatigue was seldom due to physical hardships. Fatigue was due to continued emotional stress—and, I believe, in part to uncertainty. This is the fatigue which does not disappear with sleep, and which has a cumulative effect. Under the conditions of 1952 in Korea, the extreme form, combat fatigue, was seldom recognized.

The question arose: Does the stress of combat lead to adrenal cortical insufficiency? Our studies permit a generalization only to the conditions in Korea. The studies were made under conditions of chronic stress, and I use the term deliberately, for I believe that it is the method or weapon by which strong men are being broken in certain parts of the world today.

The studies, obviously, had to be made in the front lines. They represent what can be achieved for the mutual welfare of our troops when problems are explained and approached on a cooperative basis.

Our primary aim was to get complete 24-hour urine collections from troops under combat stress. With the cooperation of the Army surgeon, the corps and division surgeons and the Commanding General of the infantry division, our officers and men gained access to the front lines to live and to work with the combat troops. Volunteers, including the company officers, were obtained because of their respect for the cooperating battalion surgeons and their corpsmen.

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*Presented 19 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

Cooperation seemed complete. The completeness of the urinary collections was roughly checked by comparing the volume and the specific gravity.

Aliquots of the collection of urine were preserved in toluene or by refrigeration and shipped to the Department of Biochemistry here at the Army Medical Service Graduate School for analysis of 17-ketosteroids and corticosteroid content. The methods of analysis have been previously described and consisted of modifications of the Zimmerman and formaldehydogenic methods. (*1*)

Noncombat soldiers served as controls. The excretion of steroids indicated normal function as indicated by examples in table 1.

Three groups of combat troops were studied. They represented different groups under somewhat varying tactical conditions between January and July 1952. An effort was made to obtain approximately 12 volunteers in each group and to study each man for three consecutive days.

The results of individual studies are demonstrated in figures 1 to 6.

Table 1. Excretion of Steroids

Subject	Day	Urine volume, cc.	17-ketosteroids mg. per 24 hours	Corticosteroids mg. per 24 hours
No. 1	1	750	15. 1	1. 4
No. 1	2	800	19. 0	0. 9
No. 1	3	740	16. 6	2. 4
No. 2	1	700	10. 9	1. 6
No. 2	2	600	11. 1	1. 7
No. 2	3	600	10. 5	1. 5
Average of 4 subjects (12 days—total)		749	13. 6	2. 0
Reported normal range			8. 0–22. 0	0. 6–2. 6

A correlation between the external environment and the steroid excretion is not always possible but table 2 indicates that the adrenal response was noted fairly uniformly throughout a group during the same period of time. These soldiers had all been under daily fire for 40 days. On the first day of the study, they were under an unusually heavy barrage. Of the 12 men studied that day, only 1 had a corticosteroid excretion which was normal. All the others were elevated. Four had an excretion increased to almost 400 percent of normal. The following day, the artillery and mortar fire tapered off and so did the adrenal response. The next 2 days were quiet so that on the fourth day, the steroid excretion had, without exception, subsided to normal.

This trend is best demonstrated by the average values shown in table 3. The 17-ketosteroid excretion was normal throughout this period.

Three soldiers shared a bunker which was in the center of the activity (fig. 1). Their bunker was destroyed by mortar fire a few hours after the 24-hour period ended and one of the soldiers was killed. Each demonstrated an increase to 200 to 300 percent in corticosteroid excretion but each had a normal 17-ketosteroid excretion.

Figure 2 demonstrates the gradual decrease in adrenal activity as the stress decreased. The maximal corticosteroid excretion did not

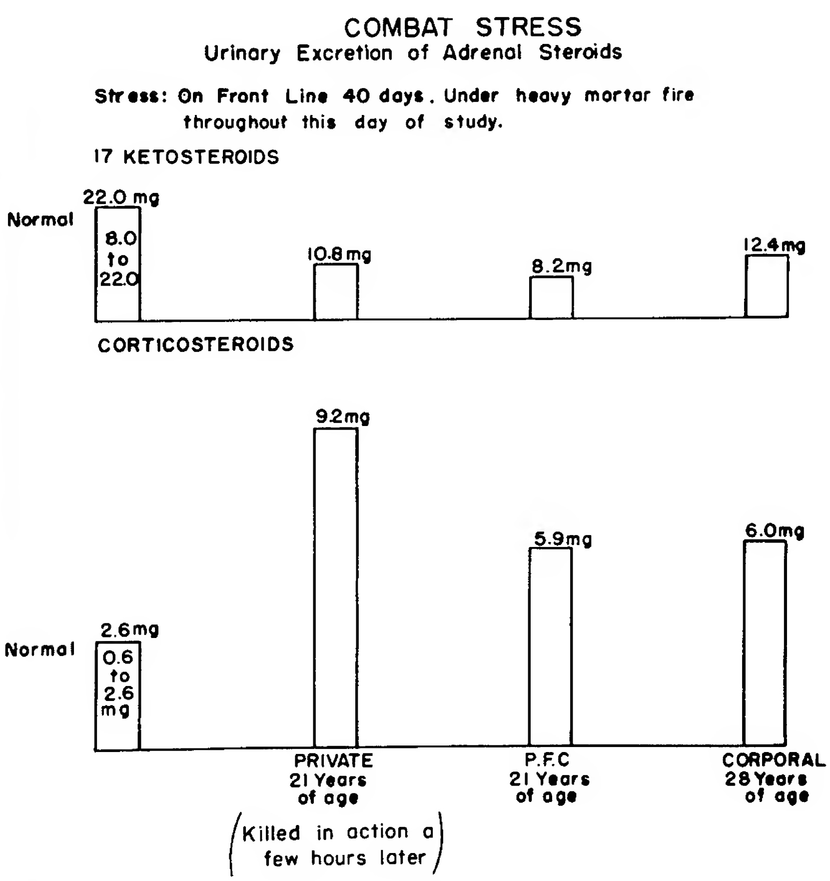

FIGURE 1. Demonstrating the response of three men who shared the same bunker on the day it was destroyed by incoming mortar fire. These men had been on front line duty for 40 days.

This represents the adrenal response to acute emotional stress after 40 days of exposure. The corticosteroid excretion is elevated to 200 to 300 percent of normal. The 17-ketosteroid excretion is normal.

always coincide with the heaviest fire (fig. 3) but, if not, followed shortly thereafter. Adrenal cortical response continued for 24 hours after the shelling had subsided (fig. 4). The adrenal response to the stress of battle appears comparable to the response of major injuries as demonstrated by figure 5. There can be no doubt that these men were under stress and that their adrenal cortex remained responsive.

A total of 35 combat soldiers were studied by this method. The excretion of 17-ketosteroids was normal. The excretion of corticosteroids was normal or elevated. The increase in excretion could usually, but not always, be correlated with the day's activity. In no instance was evidence of adrenal insufficiency detected.

In a different phase of the study, an officer under long-standing nervous tension was found to be developing an anxiety state which was

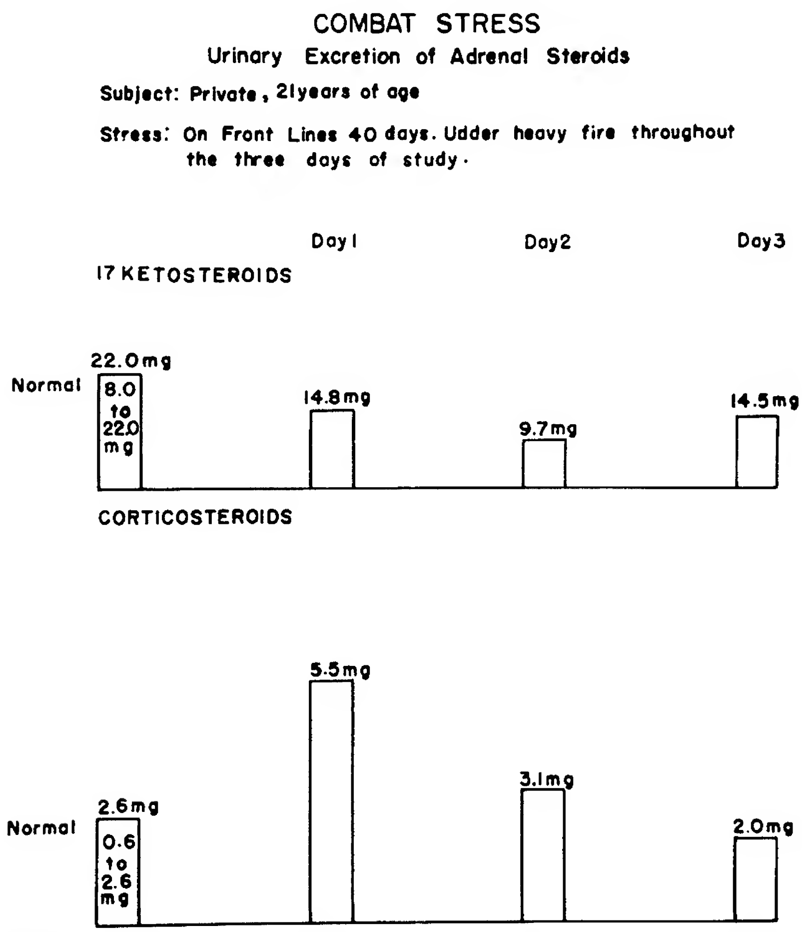

FIGURE 2. Demonstrating a subsidence in the adrenal cortical response in this soldier in the face of continued danger.

Table 2. Combat Stress—Corticosteroid Excretion** by Combat Soldiers, Milligrams per 24 Hours*

Date	Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
11 May 1952	Heavy artillery fire	3. 9	6. 2	-----	5. 3	5. 9	5. 0	5. 5	-----	9. 4	4. 9	8. 6	8. 6	2. 6	-----	9. 2
12 May 1952	Fewer incoming shells	6. 3	2. 1	4. 4	6. 2	-----	-----	3. 1	4. 5	4. 3	-----	-----	-----	1. 0	1. 6	-----
13 May 1952	Rain—quiet	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
14 May 1952	Quiet day	2. 0	2. 1	1. 0	1. 5	-----	-----	2. 0	2. 1	1. 1	1. 2	-----	1. 0	1. 0	1. 1	-----

*All men on front line for previous 40 days.
**Normal 0.6—2.6 mg. per day.

becoming incapacitating. After 30 days of increasing tension, his corticosteroid excretion was found to be high (fig. 6). Adrenal insufficiency was not an associated factor.

The next step was to study the wounded man to determine if he could manifest the normal adrenal cortical response to physical injury. This was approached in two ways.

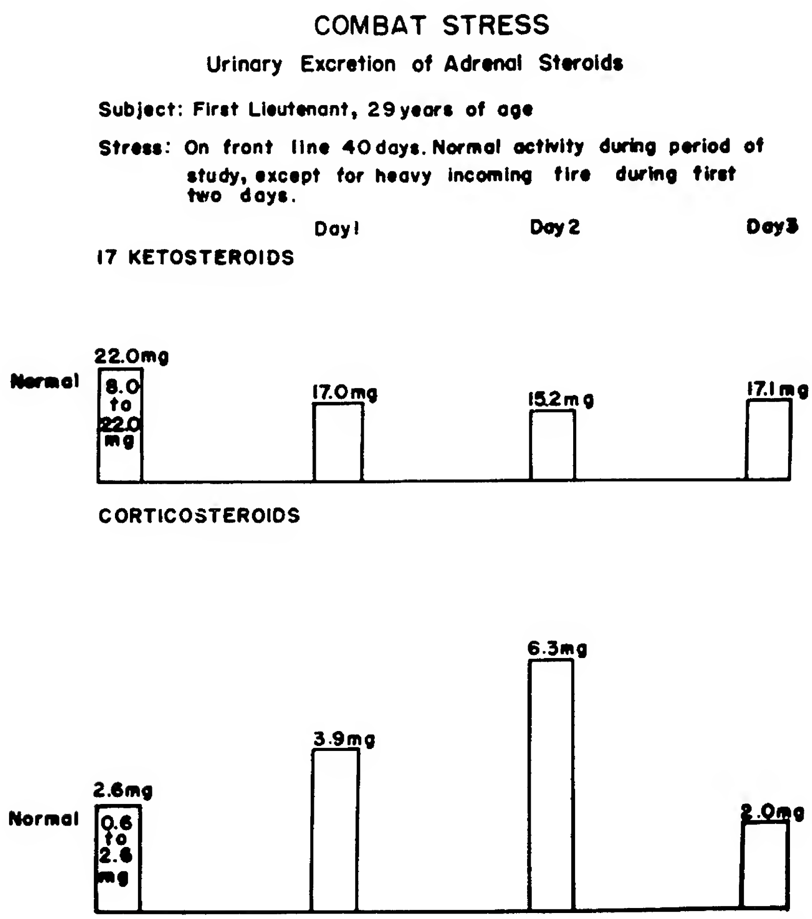

FIGURE 3. After 40 days of exposure, this officer responded to an increased hazard by an increase in excretion of corticosteroids. The 17-ketosteroid excretion remained normal.

First, 64 casualties were studied with eosinophile counts immediately after injury. Each demonstrated a typical adrenal cortical response as manifested by a marked depression in the concentration of circulating eosinophiles (*1*).

An additional 20 casualties were selected for continued study during the day of injury and the succeeding 7 to 14 days thereafter (*1*).

TABLE 3. *Combat Stress—All Men on Front Line 40 Days—A Study of 15 Soldiers*

Date	Activity	Average corticosteroid excretion * milligrams per 24 hours
11 May 1952	Heavy artillery fire	6.3 mg.
12 May 1952	Fewer incoming shells	3.7 mg.
13 May 1952	Rain—quiet	
14 May 1952	Quiet day	1.5 mg.

*Normal range 0.6–2.6 mg.

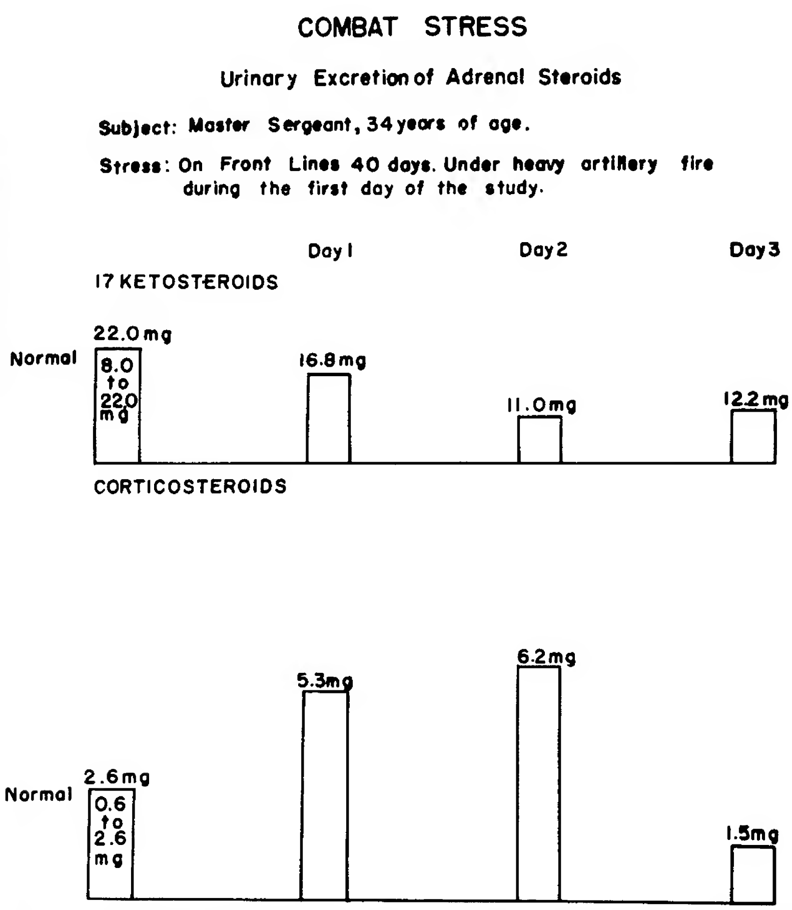

FIGURE 4. Demonstrating a continued response for 24 hours after the shelling had subsided.

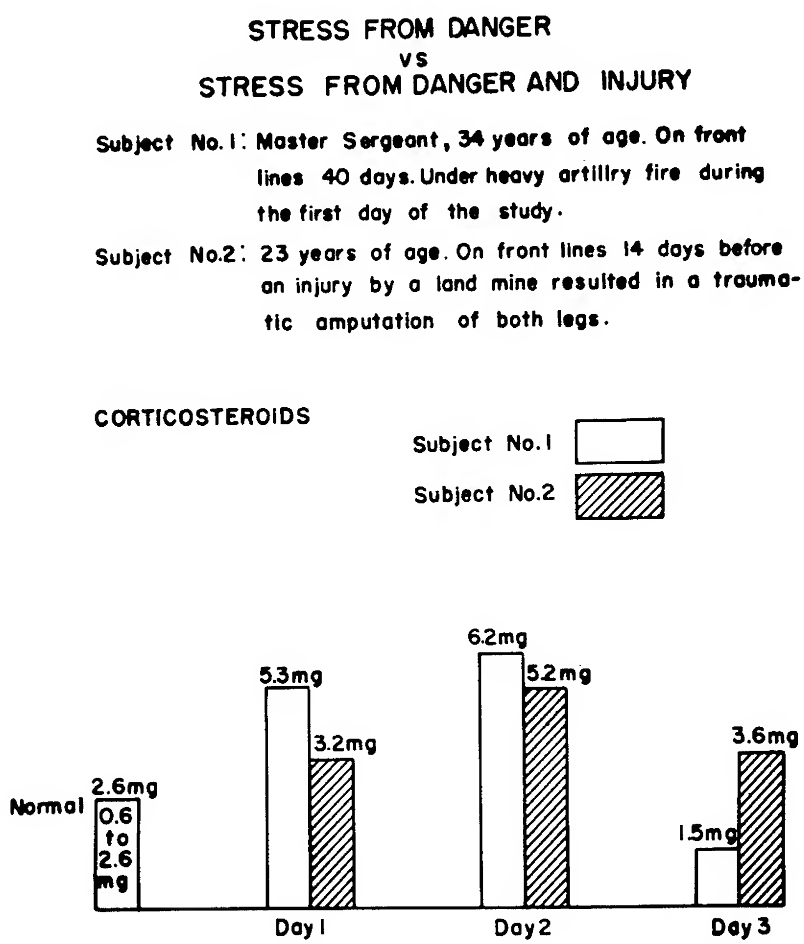

FIGURE 5. The response to danger appears approximately equal to the response to major injury in these specific instances. Both subjects demonstrate fairly representative findings.

The following two patients are typical of the group.

Patient No. 6

Twenty-one-year-old American soldier, weight 175 pounds, blood type A, in Korea for 30 days and in combat 20 days. This soldier was wounded by multiple shell fragments at 0330 hours, 3 August 1952. Arriving at the battalion aid station 1 hour later, he was given 15 mg. of morphine, 600,000 units of penicillin, and 0.5 cc. of tetanus toxoid. On arrival at the hospital 5 hours after injury, his blood pressure was 148/78 and his pulse rate 104 per minute. He was pale and considered to be in incipient shock. After 1,500 cc. of blood in the preoperative ward, his pressure was 160/100. His wounds included a perforation

of the right side of the chest, diaphragm, and liver. The wound of the right lobe of the liver would easily admit four fingers. In addition, he had multiple small penetrating wounds of three extremities.

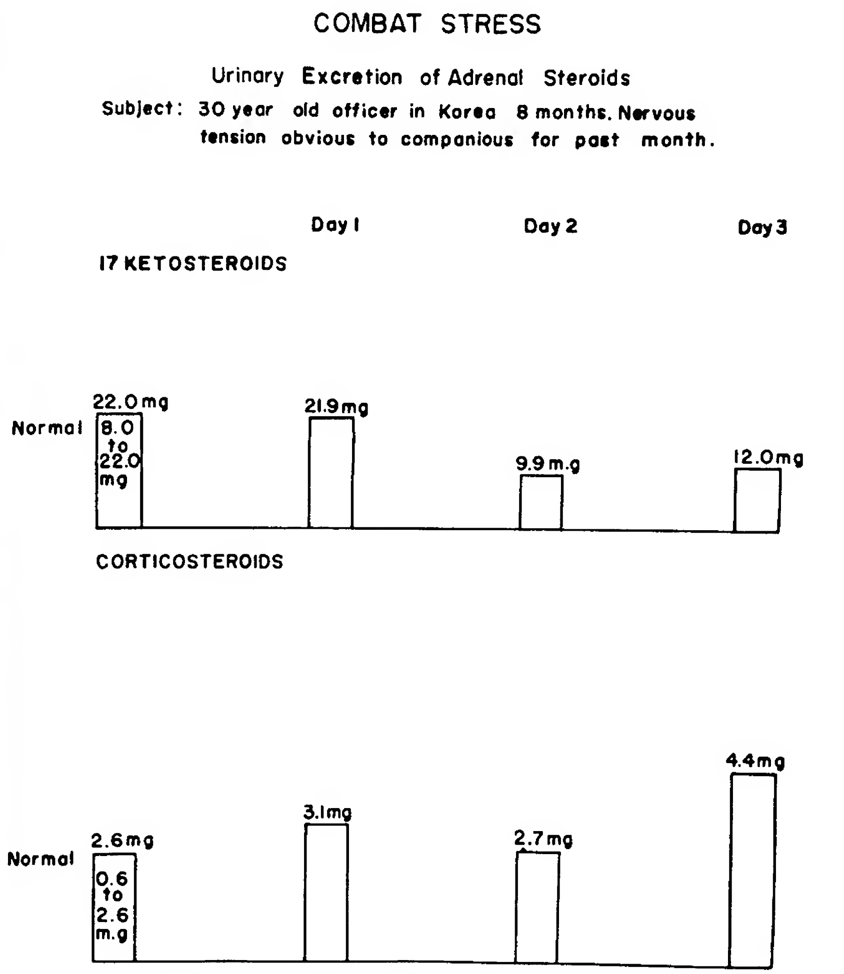

FIGURE 6. This officer had not been under condition of combat nor actual personal danger. Nervous tension became as intense as in soldiers in the front lines. Adrenal function appears to be increased during a representative period of time and activity.

A laparotomy was performed and the hepatic wound drained. The soft tissue wounds were débrided. Ether, oxygen, and nitrous oxide were given by inhalation. His operative course was smooth, his pressure ranging about 120/75, pulse 120. Another pint of blood was given during operation. Thoracentesis was repeatedly performed postoperatively until on the fifth day a tube drainage of the right side

of the chest was performed. Blood loss was estimated at 500 cc. during operation. His subsequent course was smooth.

This soldier demonstrated the rise in corticosteroid excretion following injury. The response subsided but was detectable again on the seventh day (fig. 7) due, perhaps, to the earlier secondary trauma of intubation of the pleural cavity. This patient's sodium intake

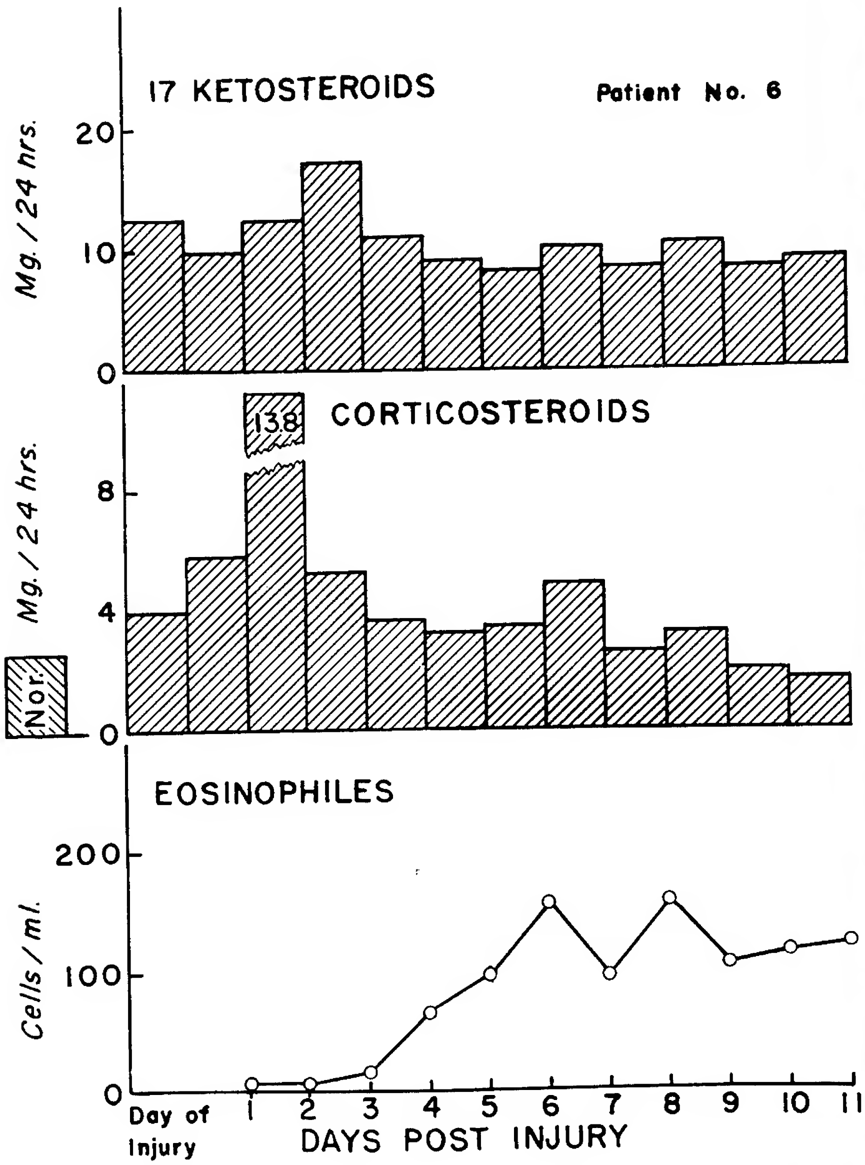

FIGURE 7. Note the fall in eosinophile concentration in the blood and the increase in the urinary excretion of corticosteroids.

was quite limited so that he was slow to develop a positive sodium balance (figs. 8, 9, and 10). The potassium diuresis was rather marked. He, therefore, demonstrated the manifestations of a rather typical adrenal cortical response to injury (fig. 11).

Patient No. 8

This soldier, 30 years of age, was wounded by mortar shell fragments at 1100 hours 20 September 1952. The injuries included traumatic amputation of both legs and both upper extremities at the forearm. He was seen shortly thereafter at the battalion aid station where he was given albumin 500 cc., morphine 30 mg., streptomycin 1.0 gram, and penicillin 600,000 units. He arrived at the hospital 2.5 hours after injury. At this time, his blood pressure could not be measured because of the limited areas exposed. His pulse rate was 102 per minute. He was pale, lethargic and dry. No peripheral vessels were visible.

Eighteen pints of blood were given intra-arterially. Meanwhile, hemostasis was obtained. The pulse averaged 130 to 140 beats per

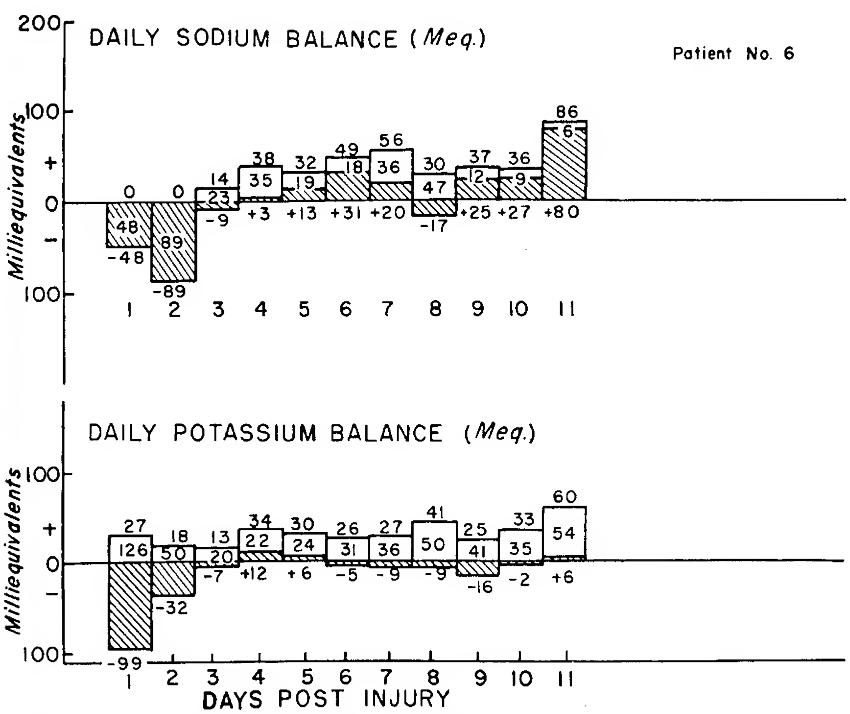

FIGURE 8. Sodium intake was zero during the first 2 days so that he was slow to develop a positive sodium balance. Potassium diuresis was marked. Figure above column represents intake, figure in column represents output, and figure below column (and shaded area) represents balance (after Moore).

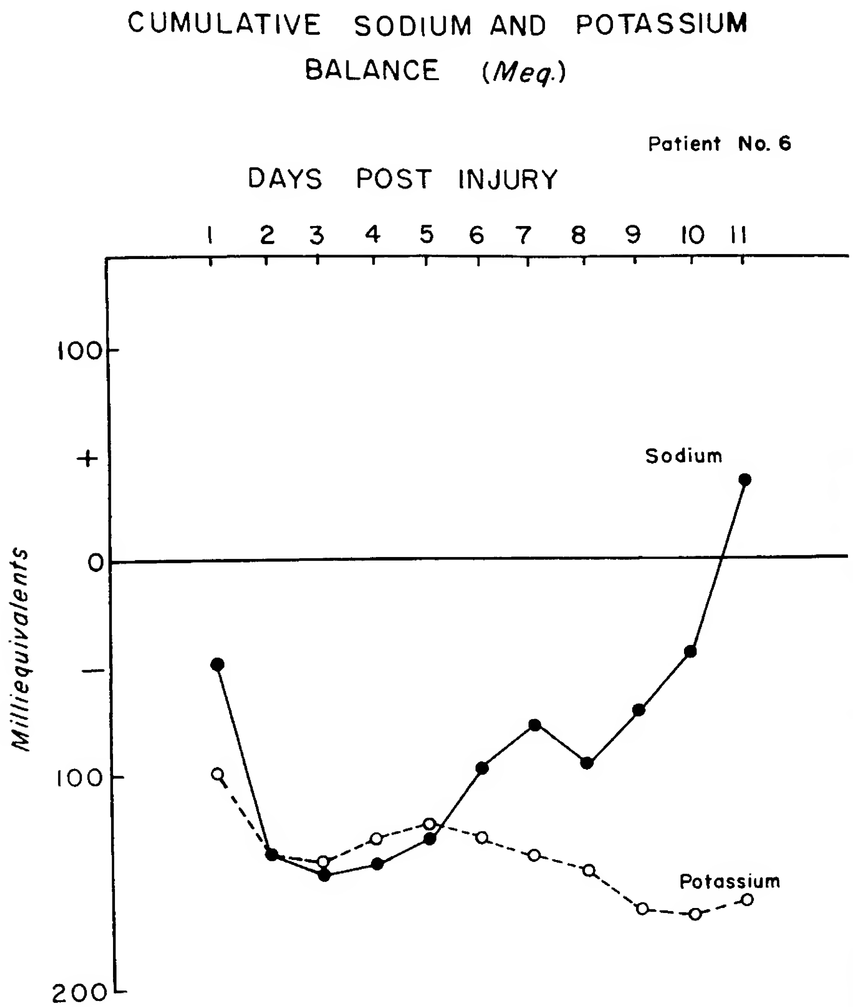

FIGURE 9.

minute and was irregular. At 2000 hours, under pentothal, oxygen and ether anesthesia, four surgical teams reamputated all four extremities. The operation required only 20 minutes but was poorly tolerated. By the end of surgery the patient had received 23 pints of blood in addition to 5 units of albumin. The following day he received three more pints of blood. His subsequent convalescence was fairly slow but uneventful.

His wounds were dressed on the sixth postoperative day. No anesthesia was used at this time.

Figure 12 demonstrates the rise in corticosteroid excretion on the day after injury. This response slowly subsided but was again noted

after the trauma of the secondary dressing on the sixth day. The 17-ketosteroid excretion remained essentially normal. Potassium diuresis and sodium and water retention (figs. 13, 14, 15, 16) were uniformly observed.

These patients were rather typical of the group. Again, each of the 20 patients demonstrated a normal response of the adrenal cortex following injury.

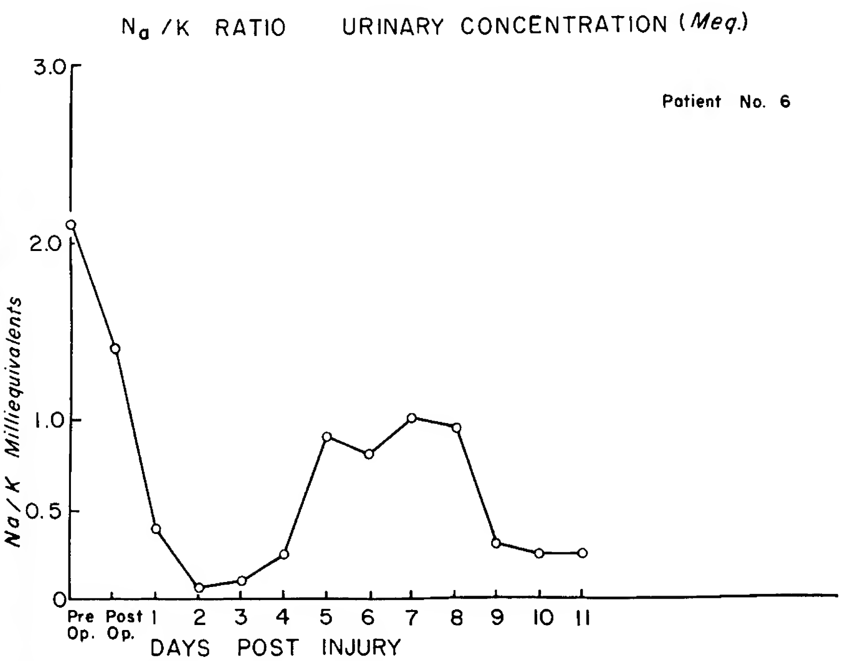

Figure 10. Note the evidence of sodium retention and potassium loss as indicated by the rapid decrease in the Na/K ratio.

Summary

A study of the combat casualty was made during the first half of 1952 on the Eastern Korean front. Adrenal cortical function appeared normal in the front line soldiers. After prolonged exposure to the stress of battle exposure, acute danger stimulated an adrenal response of the magnitude found after severe combat injury.

Following combat injury, each soldier studied demonstrated a response of the adrenal cortex.

Under the conditions of the study in Korea, therefore, adrenal insufficiency was not found to result from combat stress.

Reference

1. Howard, J. M., Olney, J. M., Frawley, J. P., Peterson, R. E., Serfin, Guerra, and Dibrell, W.: Studies of Adrenal Function in the Combat and Wounded Soldier. Report to the Army Medical Service Graduate School, 1954.

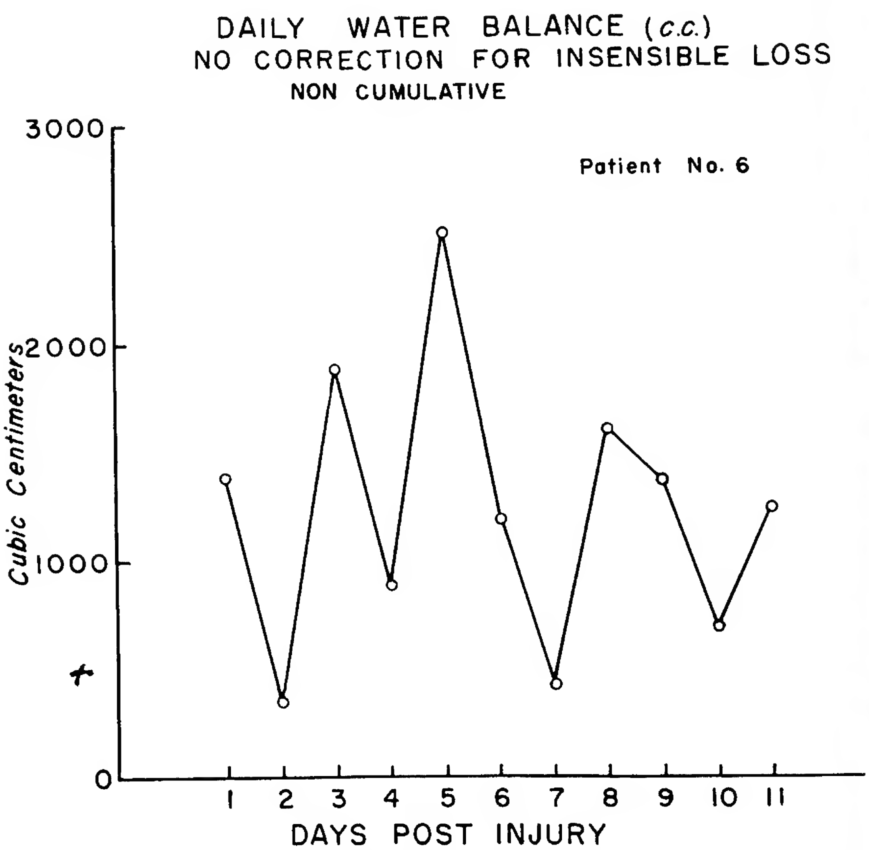

FIGURE 11. Demonstrating a positive water balance for at least the first few days.

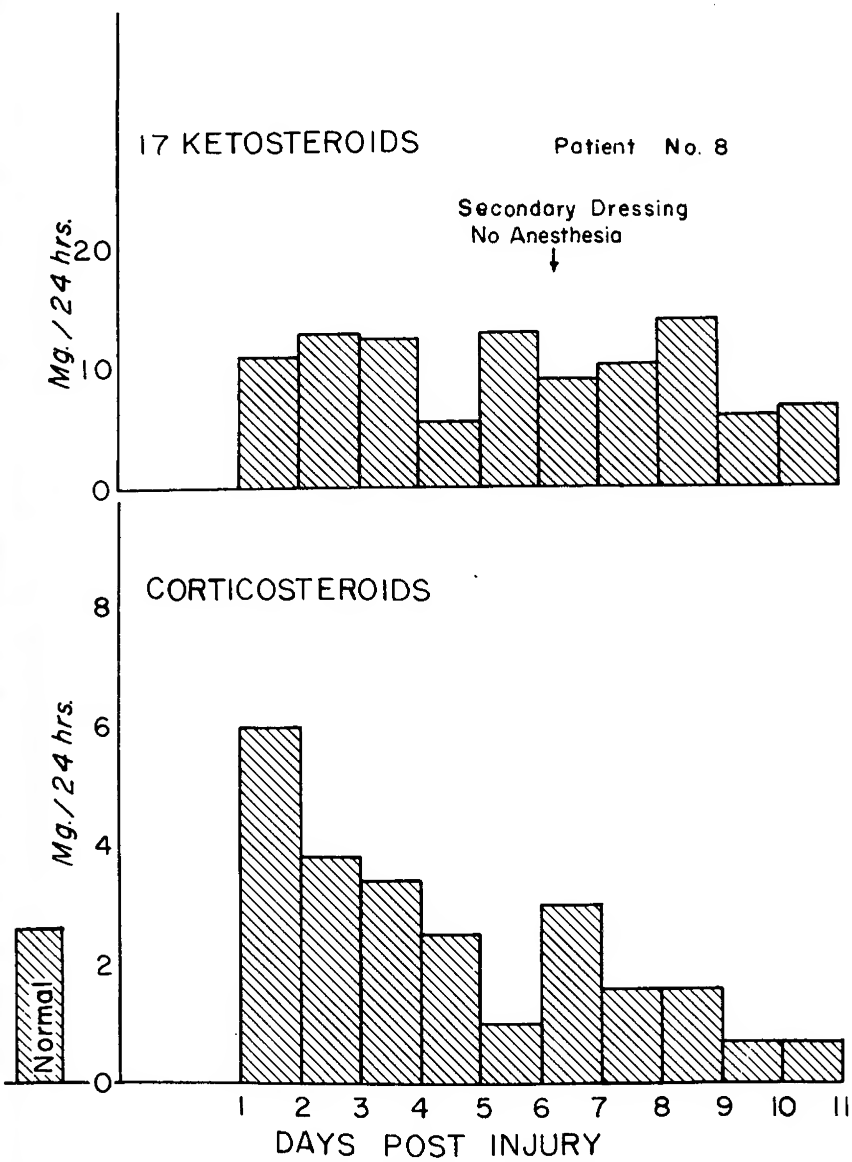

FIGURE 12. The corticosteroid excretion was elevated on the day after injury and thereafter gradually returned to normal. It again increased following secondary trauma on the sixth day. The 17-ketosteroid excretion (normal 8 to 22 mg.) remained essentially normal.

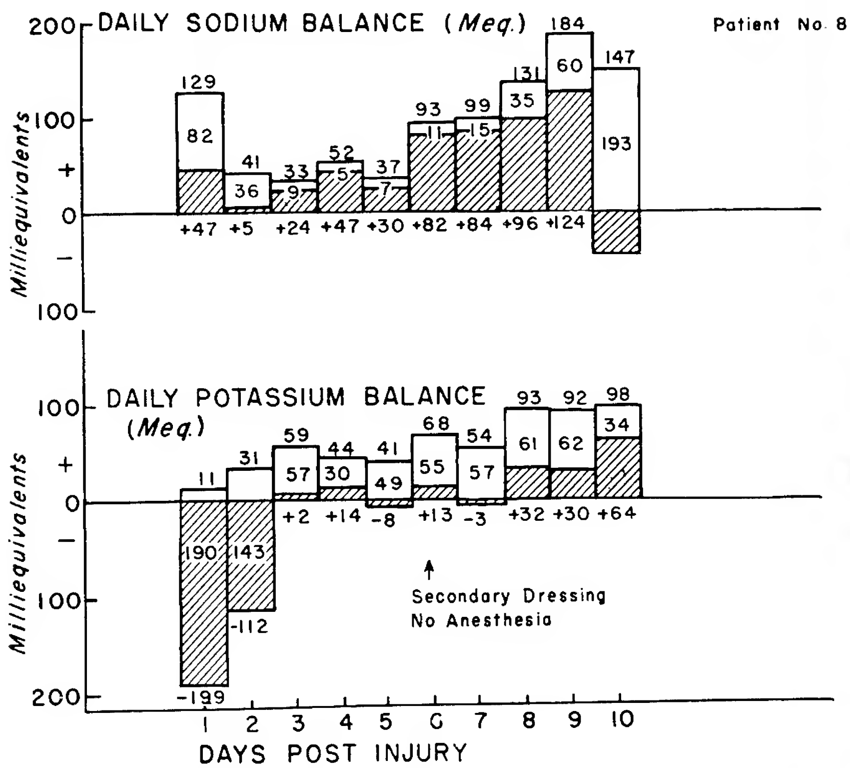

FIGURE 13. Sodium retention was marked throughout the first 9 days. Potassium was lost for 2 days and then conserved. Figure above column represents intake, figure in column represents output, and figure below column (and shaded area) represents balance (after Moore).

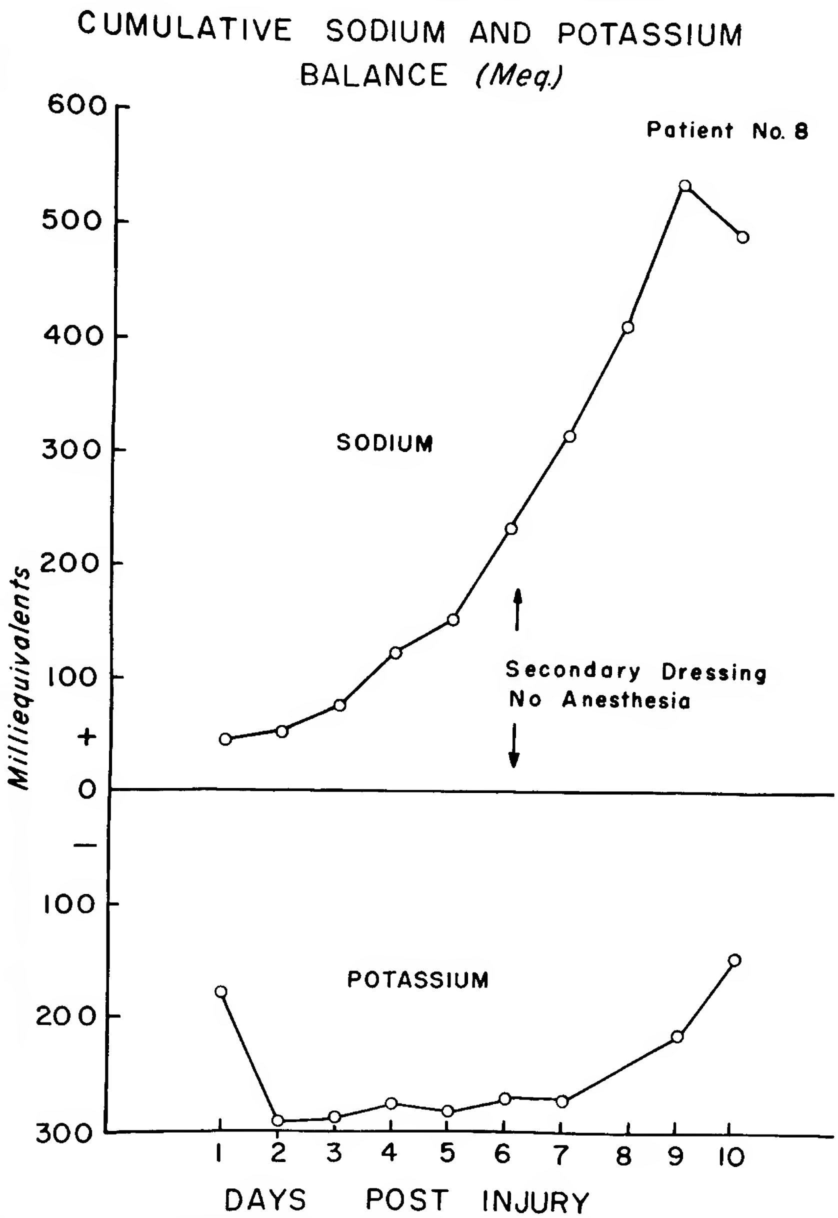

FIGURE 14. Demonstrating the continuing change.

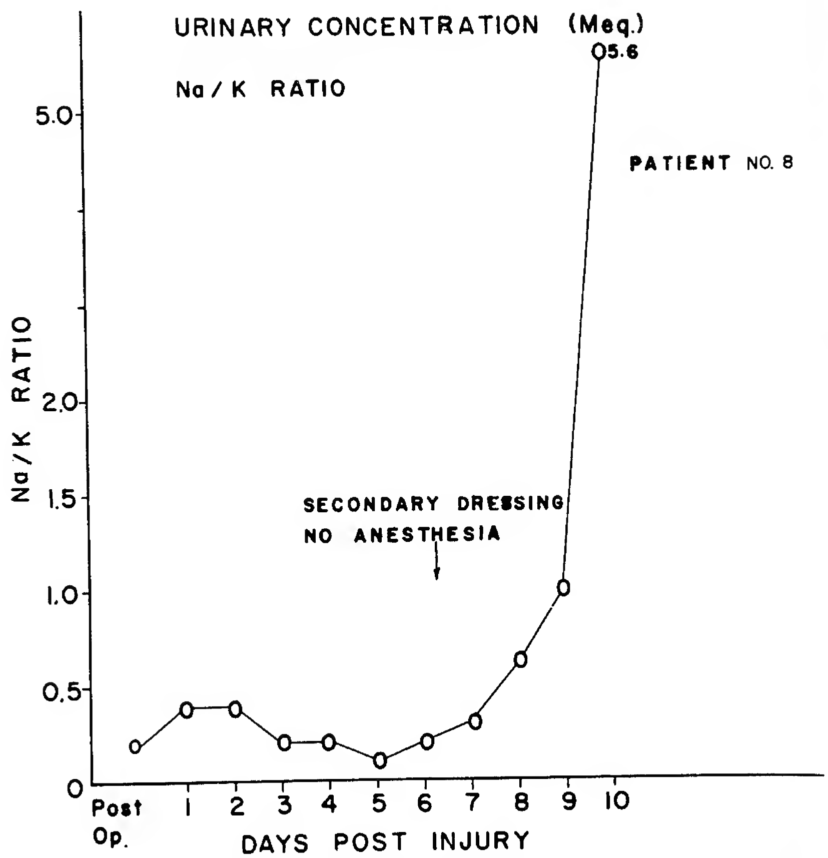

FIGURE 15. Potassium was excreted in larger amounts than sodium throughout the first week.

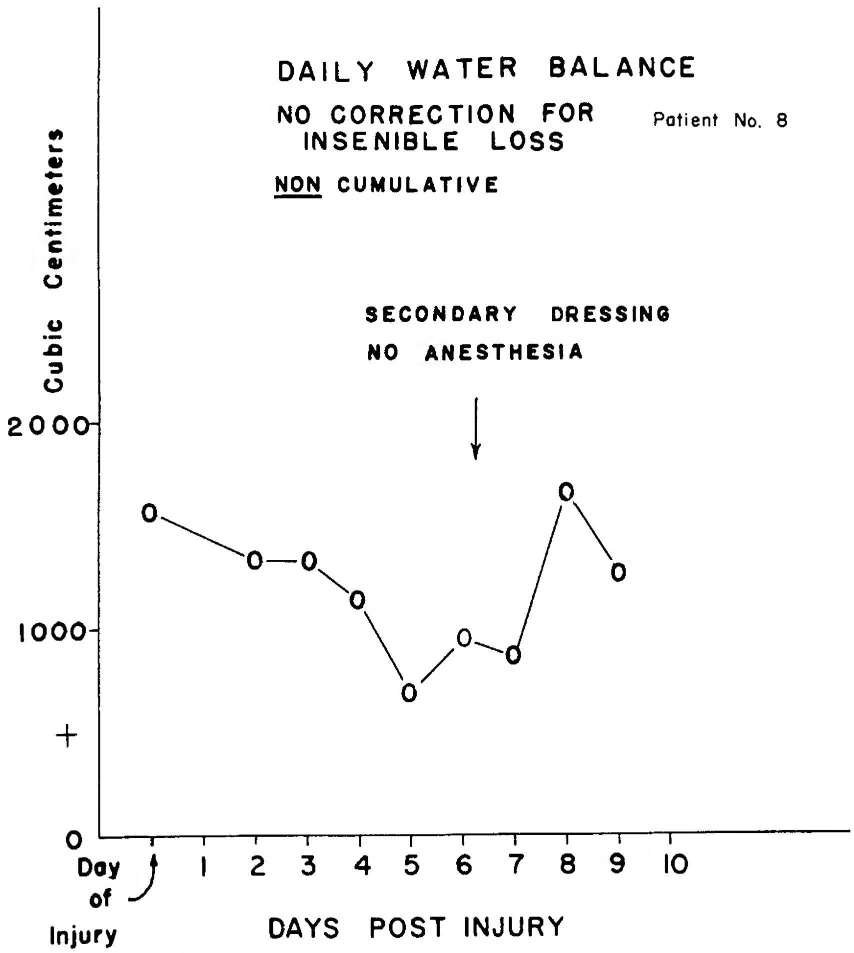

FIGURE 16. Demonstrating water retention early.

A STUDY OF COMBAT STRESS IN KOREA, 1952: PHYSIOLOGIC AND BIOCHEMICAL*

FRED ELMADJIAN, PH. D.

AND

STANLEY W. DAVIS, PH. D.

In late August 1952 a team, consisting of personnel from the Army, Navy and Operations Research Office, went to the Far East to study the physiologic, psychologic and psychiatric aspects of combat stress of infantrymen. The preliminary report has already been made (*1*). This is a presentation of the physiologic and biochemical data compiled and analyzed since that preliminary report, with emphasis on the adrenal cortical function and steroid metabolism. The data include urinary, 17-ketosteroids, Porter-Silber chromogens, sodium, potassium, urea and uric acid.

Subjects

Two principal groups of men in combat were studied: (1) A group of men designated as "Able Co.," who experienced an acute combat situation in which they were the lead company in an unsuccessful attempt to regain a hill position. Data to be presented from this group include a pre-combat (A) sample obtained some 2 hours after they were briefed for the attack; another sample (B) some 17 hours after they were returned to the rear (this group includes only five men who were in the original group), and a 4-day (C) and 22-day (D) follow-up after the principal engagement. (2) The second and smaller group consisted of men who experienced a prolonged and sustained action defending the hill position after it was taken, against enemy counter-attacks for 5 days. No precombat (A) data were obtained from this group, which was designated as "George Co." However, data will be presented on (B) some 15 hours after they were relieved and some 10 days (C) after the defensive action.

These data are compared with a group of controls, men who were stationed immediately behind the main line of resistance in blocking position. Data of a group of psychiatric casualties will also be presented.

*Presented 19 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

A second aspect of the data to be reported includes a small sample of each group, who were selected at random, to whom ACTH was given to test adrenal cortical reserve or responsiveness. Previous to testing the men in the combat area, a group of men in Japan (Camp Omiya) were given the ACTH in a test-retest situation to determine reproducibility in the same individual of the adrenal reserve of capacity.

Methods

Samples (not including the ACTH test) represent collections over a mean time of about 3 hours. Except for (B) samples of both Able and George Co., the majority of samples represented before-noon urines. Those receiving ACTH were injected with 2 cc. of Wilson's Gel preparation in the afternoon and collections were made over approximately a 15-hour period; the last voiding being the following morning about 5 to 6 a. m. See details for collecting period in tables 1, 2 and 3.

The method for extraction of 17-ketosteroids was that described by Pincus (*2*). The urine was hydrolyzed and extracted with ether and prepared to the point of Girard separation in Korea. The extracts in test tubes were flown to the United States and steroid analyses were completed at the Worcester Laboratories. The Butanol extraction for Porter-Silber chromogens and preparation of the samples for analysis were completed in Korea and sent in test tubes to Dr. Peter Forsham at the Metabolic Institute at the University of California Hospital, for the conduction of the Porter-Silber reaction. The method used was a modification of the Reddy method (*3*). Methods used for electrolytes, urea and uric acid have been previously described (*1*).

Results

Control and Combat Data

In table 1 and in figure 1, we present the mean 17-ketosteroid output values as mg. per hour in the various control and combat groups. In table 1 group (c) Able Co. A minus officers has been set up separately for two reasons: (1) officers contributed urines to the precombat (A) series but not to the subsequent ones, and (2) the officers exhibited, as a group, an extremely high output level of 17-ketosteroids (17-KS). The average (A) output value for the 5 officers was 1.07 ± 0.187 mg. per hour, whereas the corresponding value for the 15 enlisted men was 0.56 ± 0.06 mg. per hour. It is deduced that either these officers at any rate were a group of "high" 17-KS excretors (*4*) or that emotional tension attributable to battle anticipation led to especial activation of the pituitary-adrenal system during the pre-combat period.

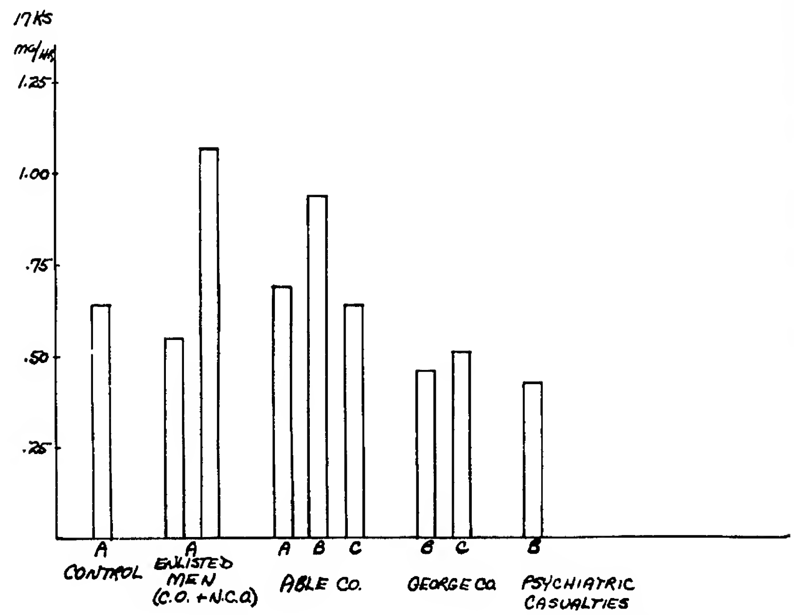

Figure 1. Urinary 17-ketosteroid excretion. From left to right the first (A) represents the mean value of the controls; the first column under the second (A) represents the mean of the enlisted men in Able before combat and the second column under the second (A) represents the mean of the commissioned and noncommissioned officers. The third (A) represents the mean of all (enlisted and officers) of men in Able A (see text).

When mg. per hour pre-combat values (c) are compared with post-combat values (d) for Able Co., a not quite significantly higher value is obtained for the latter period. In contrast the post-combat values (f) for George Co. are significantly lower than both the Korean control (a) and the post-combat (d) Able Co. values. There are no other statistically significant differences between the various sets of data. It is notable, however, that the psychiatric battle casualties (h) exhibit the lowest mg. per hour output, indicating no stimulation, but rather a damping of the 17–KS output.

The Na/K ratios are depicted in figure 2. We note that in the control group we have fairly good agreement between A and A′ (test-retest at 1-week interval), somewhere around three as a value. However, in observing the data on Able Co. we find that A of Able has a relatively low ratio, indicating some degree of adrenal cortical activity with respect to electrolytes and, furthermore, that it is still low in B. However, in C value we find that the value comes back towards normal, in fact a little above normal, and that this continues in D. With regard to George Co. we find that the ratio is high on the

Table 1. Urinary 17-ketosteroids of Combat Infantrymen in Korea, 1952

Group studied	Date	Time sampled	Number	17-KS
(a) Korean controls	26, 27 Oct	9:00 a. m.–12:30 p. m.	24	0. 64±0. 04
(b) Able Co. A	13 Oct	3:00 p. m.–5:30 p. m.	20	0. 69±0. 08
(c) Able Co. A minus officers.	13 Oct	3:00 p. m.–5:30 p. m.	15	0. 56±0. 06
(d) Able Co. B	15 Oct	12:30 p. m.–4:00 p. m.	20	0. 93±0. 19
(e) Able Co. C	19 Oct	6:00 a. m.–1:00 p. m.	20	0. 64±0. 08
(f) George Co. B	21 Oct	1:30 a. m.–6:00 a. m.	10	0. 46±0. 04
(g) George Co. C	30, 31 Oct	11:00 a. m.–5:00 p. m.	12	0. 52±0. 03
(h) Psychiatric casualties.	10, 14 Oct	(3) 2:00 a. m.–5:00 a. m. (2) 7:00 a. m.–3:00 p. m.	5	0. 43±0. 06
		t	*P*	
Significances	(c, d)	1. 85	<0. 1	>0. 05
	(a, f)	3. 16	<0. 01	
	(d, f)	2. 43	<0. 05	>0. 02

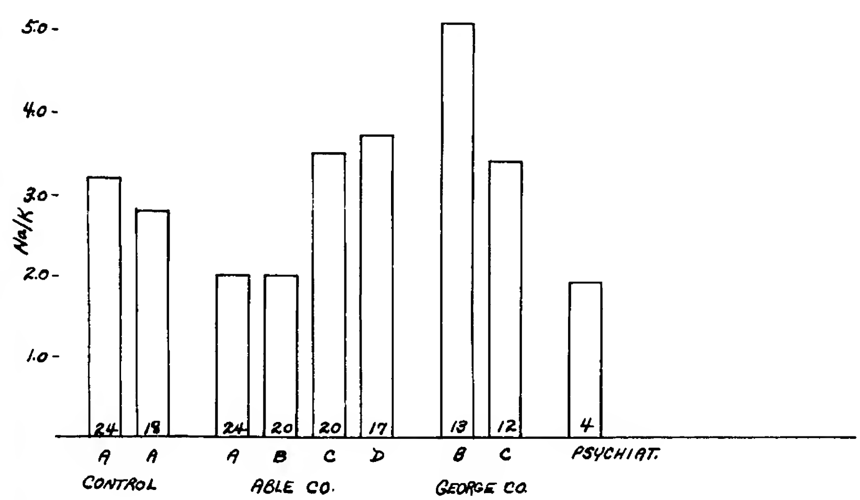

FIGURE 2. Urinary sodium potassium (molar) ratio. Numbers at the base of the open columns indicate the number of determinations included in each group.

average, indicating hypoadrenal activity. Then, some 9 to 10 days later we find that the value has returned back towards normal. The psychiatric group shows a low Na/K ratio, indicating some degree of adrenal cortical activity, in fact the same degree of activity as that of Able A or B, but with a very low 17–KS.

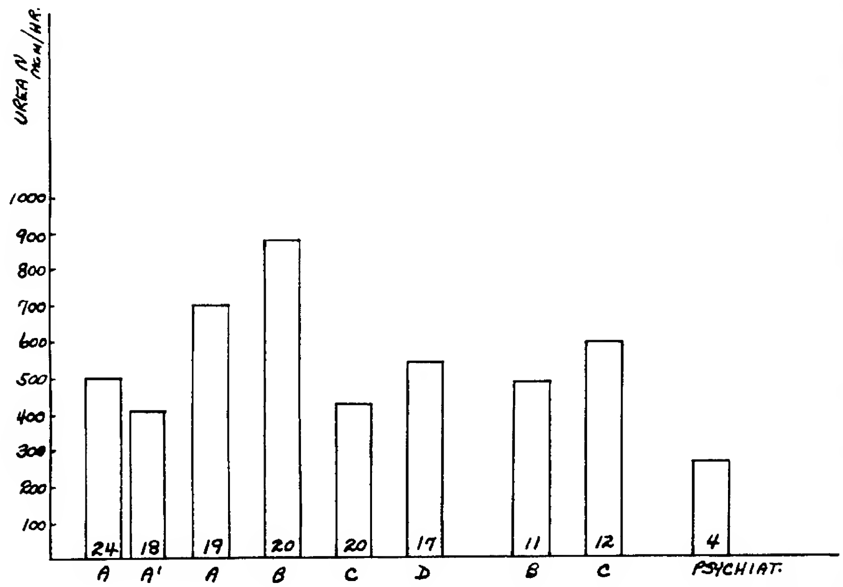

FIGURE 3. Urine urea nitrogen excretion. Figures at base of open columns indicate number of determinations included in each group.

Figure 3 shows the urea nitrogen in terms of mg. per hour. We note that in the Korean controls A and A′ we have fairly decent agreement, namely, within 400 to 500 mg. urea nitrogen per hour. In A of Able there is an increase; this increase is only of marginal significance. In B we have a real increase in the urea nitrogen, indicating a significant protein catabolism (almost doubling the urea nitrogen output above that of the normal controls). In C we see this return of urea nitrogen back towards its normal value and in D a rather slight increase, but not significant. In the case of the chronic stress situation we find that rather than a nitrogen catabolism, the value is in the normal range, and in the post-stress the C value increases somewhat though not significantly. The psychiatric group shows a decreased urea output. This value is quite low and significantly lower than the controls. It should be pointed out that in the B of Able, the increased urea nitrogen excretion is reflected in the blood with a very significantly high urea value; almost 20 mg. per 100 cc. urea nitrogen in the blood.

Figure 4 contains 17–KS values of those individuals of Able on whom we have both B and C values. We note that there are from B to C some decreases and some increases in 17–KS. We also note that the decreases are predominant. The data contributing to the large S. E. also are evident in B of Able. We will see what relationship these values of Able B have to the other indices, such as Na/K, urea and uric acid.

In figure 5 we have a scatter diagram of the Na/K ratio against the 17–KS of Able Co. B, indicated by the dots with the circles around them and the X, indicating the George Co. B group. The correlation coefficient of the Able group was −0.6, but was not significant. However, we note that the extreme values in Able Co., those who had a low 17–KS, are those who have a high Na/K ratio and the converse, the low Na/K ratio individuals, are those who have a high 17–KS. We note that in the George Co. (the X's) they are scattered along the low 17–KS and high Na/K ratio area.

Figure 6 shows the urea nitrogen mg. per hour against 17–KS in mg. per hour. We have a very good correlation of +0.74 and a significance of <0.01. Here again we note that the data of George Co. B are clustered around the low 17–KS and low urea areas.

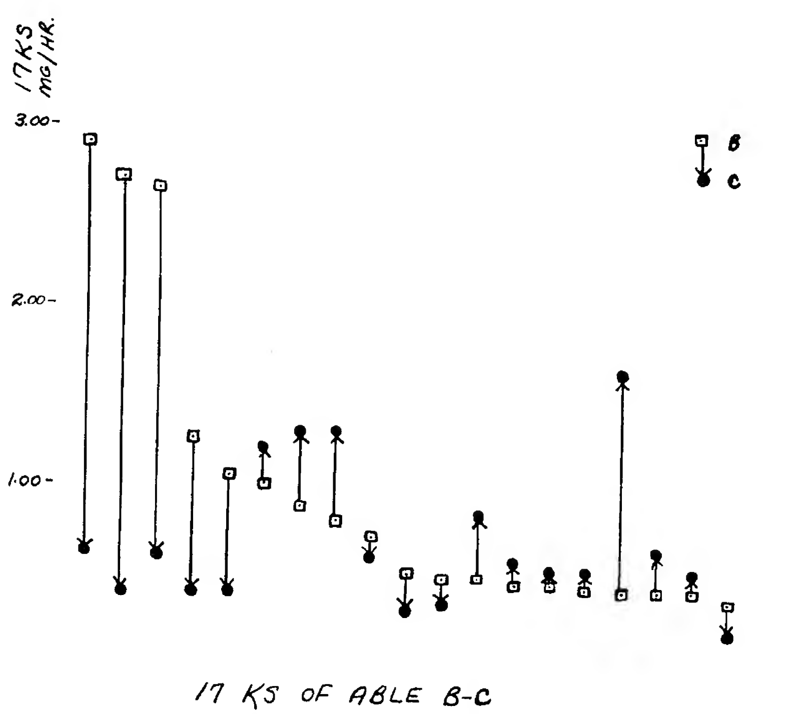

FIGURE 4. 17-ketosteroid changes of individuals of Able Co. on whom both B (17 hours after battle) and C (4-day followup) were obtained.

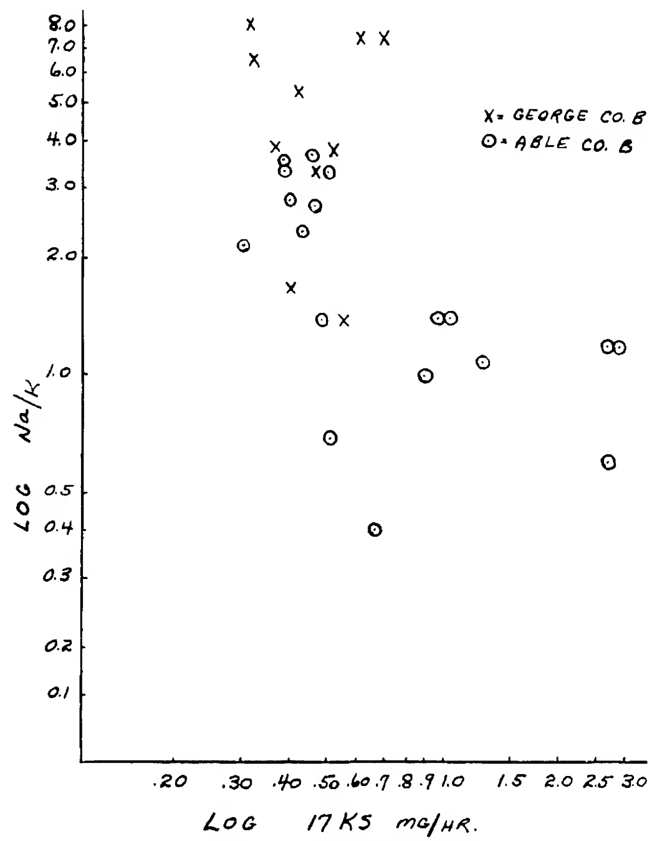

FIGURE 5. Relationship of the Na/K ratio with 17-ketosteroid excretion of both Able Co. B and George Co. B.

We have in figure 7 the same picture as that with the urea when uric acid is plotted against 17-KS. The r here is +0.54, with a significance of <0.01. In general, we see from these data that Able Co. B shows increased adrenal cortical activity in the indices examined between 17-KS and Na/K with catabolism as shown by the urea and uric acid output. The catabolism is evident also with higher creatinine values. This is not apparent in the chronic group, namely, George B, where we have no increase in 17-KS; the nitrogen metabolism is of normal range. In the psychiatric group we find that there is a low 17-KS, but, unlike George B, a low 17-KS with some degree of electrolyte activity.

ACTH Tests

In table 2 are the 17-KS data on the group of seven soldiers stationed at a rehabilitation center in Japan (Camp Omiya), and subjected to an initial (A) and a repeat (B) ACTH test with urine

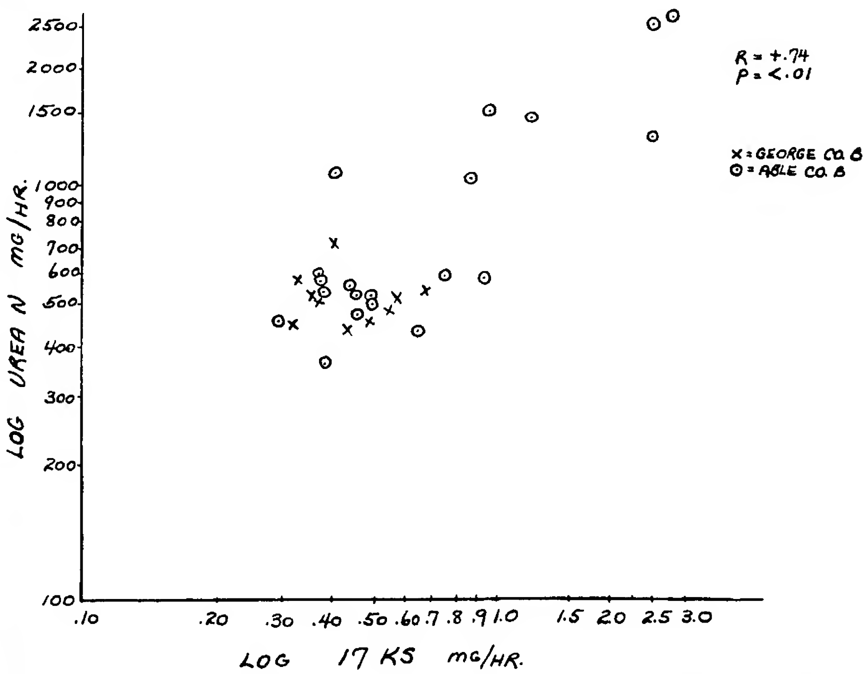

FIGURE 6. Scatter diagram of urinary urea nitrogen excretion and the 17-ketosteroids of both Able Co. B and George Co. B.

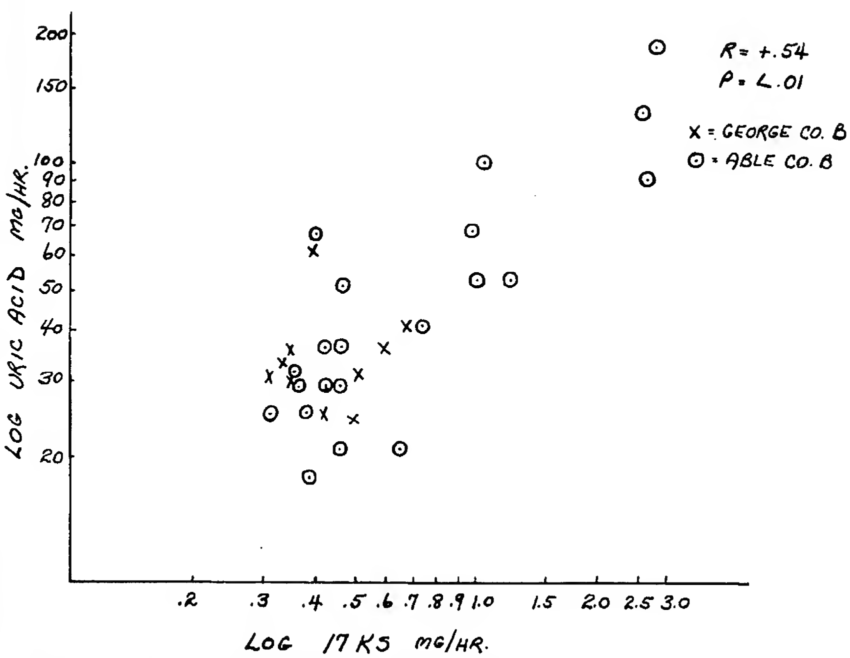

FIGURE 7. Relationship between urinary uric acid excretion and 17-ketosteroids of both Able Co. B and George Co. B.

collected from the 15 hours following ACTH administration. No pre-injection samples were determined. Whether the data are calculated as mg. 17–KS per hour or per 100 mg. creatinine, remarkably high and significant correlations between the data of the two tests are had, indicating that with the ACTH used the 17–KS response is remarkably uniform and highly characteristic for each individual.

*Table 2. Reproducibility of ACTH Test—September 16–24, 4 days between A and B**

	17–KS, mg./hr.		17–KS mg./100 mg. Creat.	
	A	B	A	B
M 7856	0. 52	0. 57	0. 69	0. 70
R 5249	. 21	. 16	. 38	. 67
W 9926	. 62	. 51	. 90	----------
J 1789	. 73	. 73	1. 14	1. 11
M 2878	. 24	. 35	. 55	. 51
M 7056	. 23	. 29	. 30	. 40
P 9139	. 06	. 15	. 10	. 26
	r=0.95		r=0.94	

*Time of each collection represented urine collected from 3 p. m. to 7 a. m. thus including overnight sample. ACTH given about 3 p. m.

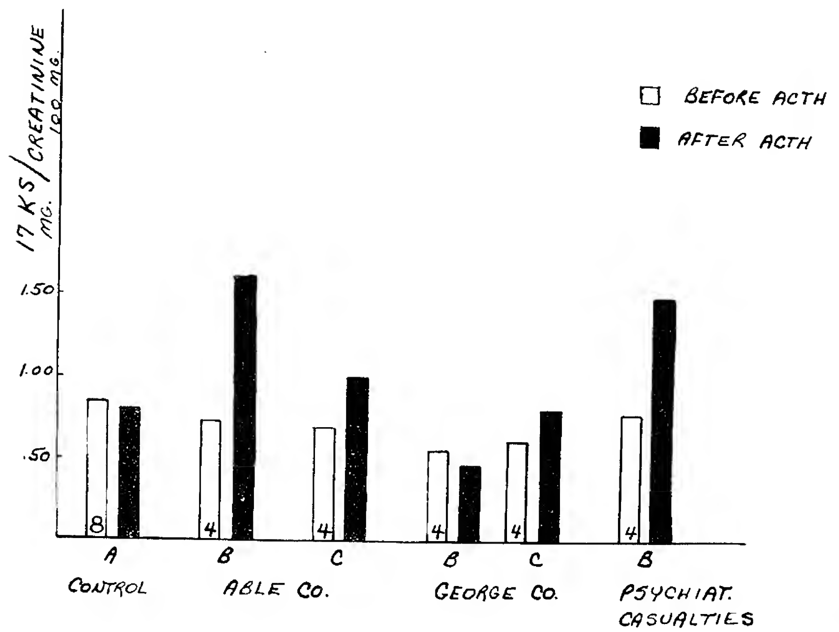

FIGURE 8. 17-ketosteroid excretion mg./100 mg. creatinine before and after ACTH. Number at the base of open bars indicates the number of individuals tested.

Table 3 and figure 8 present the mean data of 17–KS for various subjects in the ACTH test. It should be noted, first of all, that the Korean controls exhibited no increase of 17–KS excretion following ACTH administration. Since the pre-injection urine collections were made between approximately 9:00 a. m. and 12:30 p. m., and the post-injection collection for the following 15 hours which included a period of sleep, this apparent lack of stimulation may in fact involve sufficient stimulation to restore toward the morning level the known decline in 17–KS output values occurring in the afternoon and during sleep (*5*).

In any event, in contrast to the control subjects, the men of Able Co. tested show increases of 17–KS output following ACTH both in the post-combat (B) period and 10 days later (C). The George Co. subjects, on the other hand, demonstrate a decline of 17–KS output following ACTH (which is particularly obvious in the mg. per hour data) during the B period, but 10 days later during ACTH an output increase occurs. The psychiatric casualties demonstrate a significant increase of 17–KS per 100 mg. creatinine in the post-combat period.

Figure 9 contains the Na/K ratio before and after ACTH. We find that on A and A′ on eight individuals we have fairly good agreement in adrenal sensitivity as noted by the Na/K ratio. We find that in B of Able the adrenal responds to the ACTH even though the pre-samples already indicate some degree of adrenal activity. In D sample (C samples were lost) we find that the Na/K ratio is high,

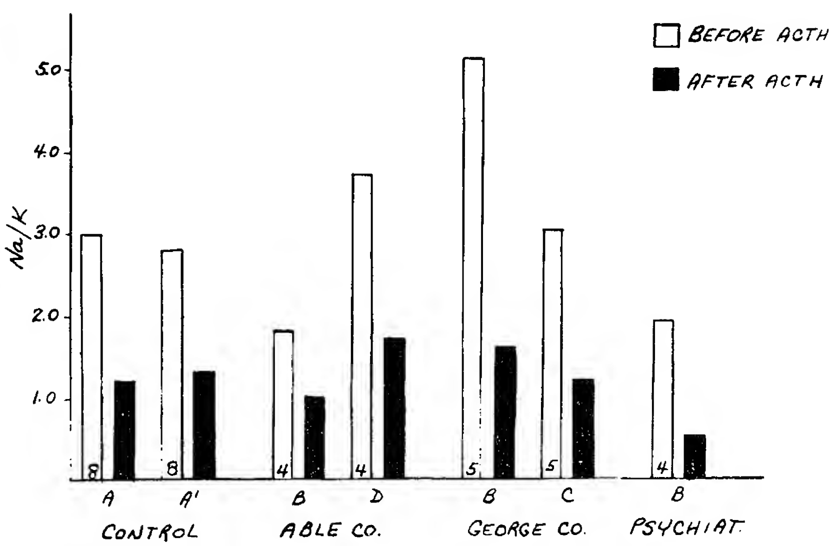

FIGURE 9. Urinary sodium/potassium (molar) ratio before and after ACTH. Number at the base of the open column represents the number of individuals included.

Table 3. 17–Ketosteroid/Creatinine Excretion Before and After ACTH

	No.	A		B		C	
		Before	After	Before	After	Before	After
Korean controls	8	0. 85 ± 0. 05	0. 79 ± 0. 09				
Able Co	4			0. 72 ± 0. 09	1. 60 ± 0. 61	0. 68 ± 0. 20	0. 96 ± 0. 07
George Co	4			0. 53 ± 0. 07	0. 43 ± 0. 06	0. 60 ± 0. 06	0. 80 ± 0. 11
Psychiatric casualties	5			0. 76 ± 0. 13	1. 48 ± 0. 13		

17–Ketosteroid Excretion Before and After ACTH

	No.	A		B		C	
		Before	After	Before	After	Before	After
Korean controls	8	0. 64 ± 0. 05	0. 44 ± 0. 07				
Able Co	4			0. 71 ± 0. 11	0. 87 ± 0. 30	0. 49 ± 0. 17	0. 62 ± 0. 21
George Co	4			0. 43 ± 0. 06	0. 27 ± 0. 05	0. 53 ± 0. 04	0. 61 ± 0. 06
Psychiatric casualties	5			0. 43 ± 0. 06	0. 72 ± 0. 32		

Note. All after ACTH included night sample: before ACTH of George Co. B represented collection 1:30 a. m.–5 a. m. ACTH was given at 3 p. m. of same day and collection was concluded next morning at about 6 a. m. Psychiatric casualties after ACTH samples did not represent overnight sample but were collected during waking hours.

that it is back to normal in the pre-ACTH samples, and is responsive to the ACTH by a reduction in the Na/K ratio. Now the interesting feature is that of George Co., where there is a hypoadrenal cortical activity as indicated by the Na/K ratio. There is, however, a response to the electrolytes after ACTH, though there was no such evidence in the 17-KS. (We will note next that the 17-KS are about the same as the P-S.) The values in C return to normal. In B of the psychiatric group we find that though the adrenals are active there is much more activity in terms of electrolytes after ACTH.

In figure 10 we have the P-S chromogens in terms of mg. per hour in three separate groups: (1) the Korean control, (2) George Co. B and C, and (3) the psychiatric group. Our Porter-Silber data were scattered because only a portion of the total samples extracted were analyzable. This in all probability is due to the high blank and other defects in this particular method used, as well as possible technical errors in preparation for analysis. (At present there is a method described by Nelson and Samuels which does not have this difficulty and the high blanks which make readings impossible have been obviated and this matter has been corrected.) We notice that in our Korean controls there are only a few determinations. The first block indicates the pre-ACTH group and is followed by the post-ACTH. In these particular data the post-ACTH group do not include any of the individuals in the pre-ACTH group. There is a clear increase as a result of ACTH injection. In B of George Co. we notice that there are some seven determinations for pre-ACTH and three for post-

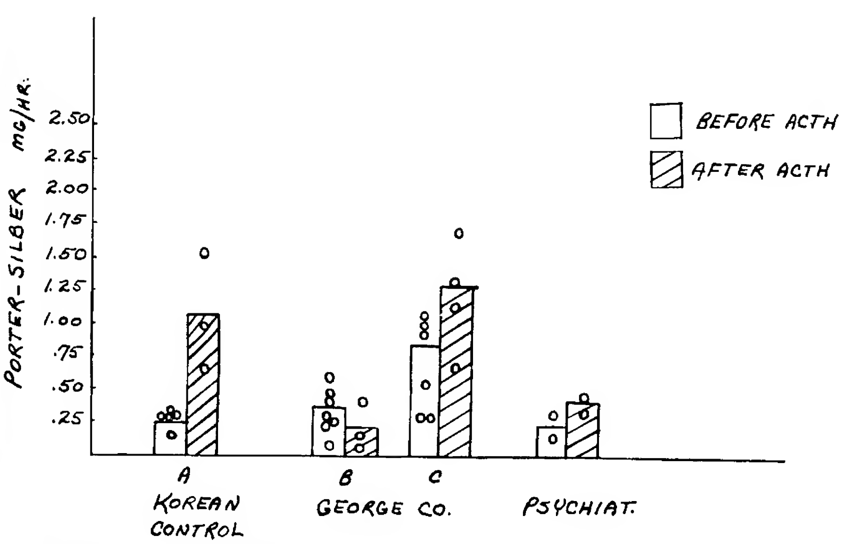

FIGURE 10. Porter-Silber chromogens before and after ACTH (see text).

ACTH. In the post-ACTH data the three are included in the pre-ACTH. We note that the adrenal is non-responsive as measured by the P–S reaction. However, in C we note that there is a response to the ACTH after 9 to 10 days, and the four individual determinations are included in the pre-ACTH. In the psychiatric group the two pre-ACTH are not the same individuals as in the post-ACTH. We note here that two features stand out: (1) There is in control samples a greater increase in the post-ACTH in the P–S than there was in the 17–KS, and (2) the adrenal non-reactivity observed in B of George Co. in the 17-KS is confirmed with the P–S reaction. However, in the psychiatric group there is a difference—we have an increased reactivity to 17–KS after ACTH, but we do not have such a phenomenon in the P–S reaction. The data in this group are admittedly small in number and rather scattered, but we feel that these data are at least internally consistent and indicate a differential steroid excretion.

In figure 11 we have a scatter of all ACTH determinations (samples obtained in Korea as well as in Japan), where the Na/K ratio is plotted against the 17–KS mg. per 100 mg. of creatinine. We observe here a correlation between the Na/K ratio and the 17–KS in terms of 100 mg. creatinine, of −0.60 and this is significant to better than 0.001.

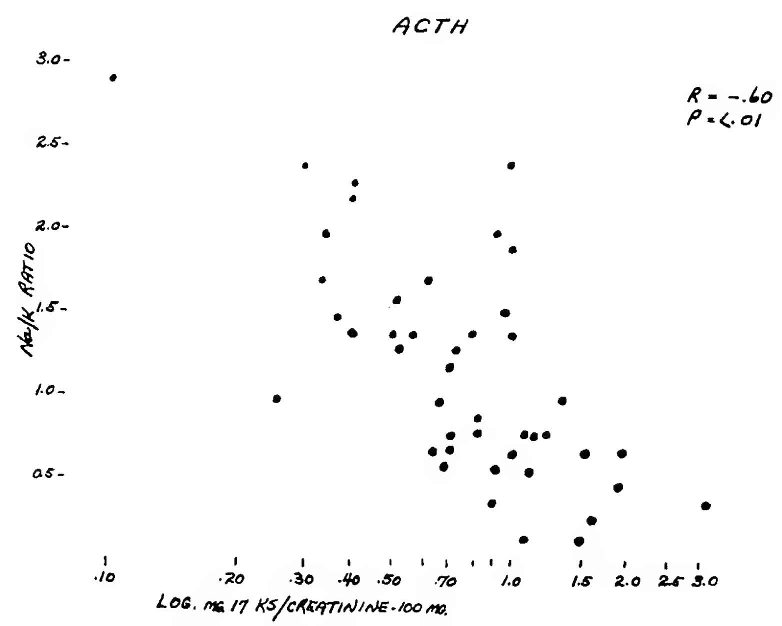

FIGURE 11. Relation of urinary Na/K ratio with 17-ketosteroids mg./100 mg. creatinine of all post-ACTH samples of all groups studied in Korea as well as Japan.

In figure 12 we have all the 17–KS determinations on which we have P–S. The scatter diagram represents P–S mg. per hour against 17–KS mg. per hour. We note two features in these data: (1) From about 0.3 mg. of the 17–KS per hour excretion to about 0.7 mg., we find the distribution of these points such that a small increase in 17–KS is related to a greater increase in the P–S. However, we note that after this critical point of somewhere between 0.7 and 0.8 mg. per hour, the 17–KS continue to increase but the P–S titer decreases. We feel that some fundamental aspect of steroid metabolism is revealing itself here with respect to stress.

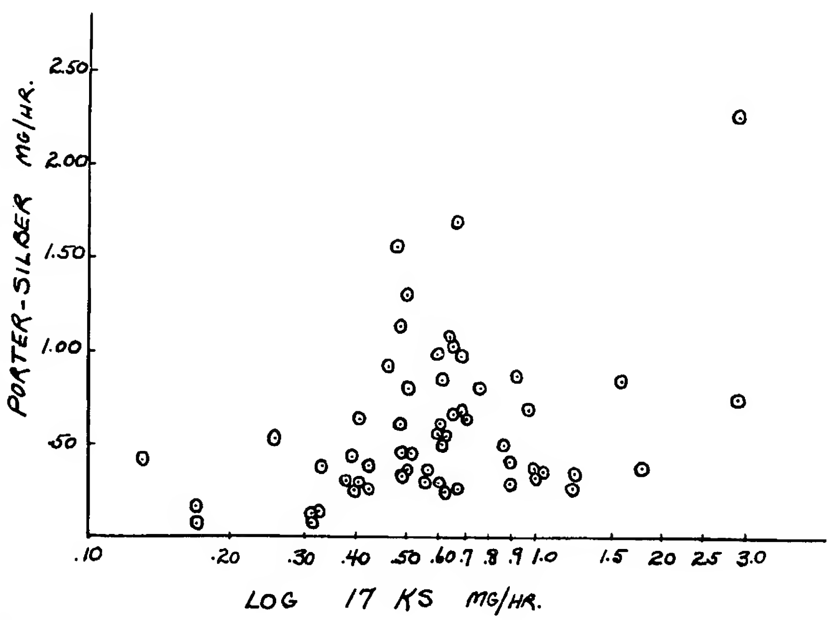

FIGURE 12. The relation of the 17-ketosteroid and Porter-Silber chromogens determined on same samples.

In figure 13 we plotted those samples which we considered as controls. They represent the Korean controls and C of George Co., and the ACTH in both these groups. We note that in this chart the solid dot represents all pre-ACTH points and the circled dot indicates post-ACTH test samples. We notice here that the distribution of the points between 0.3 mg. and 0.7 mg. is in large portion if not practically all represented by control value, in which case we have small 17–KS increases with very large P–S increases (fig. 12). Figure 14 depicts all samples which are considered as after-combat samples. We note here that the 17–KS values are high when compared with P–S.

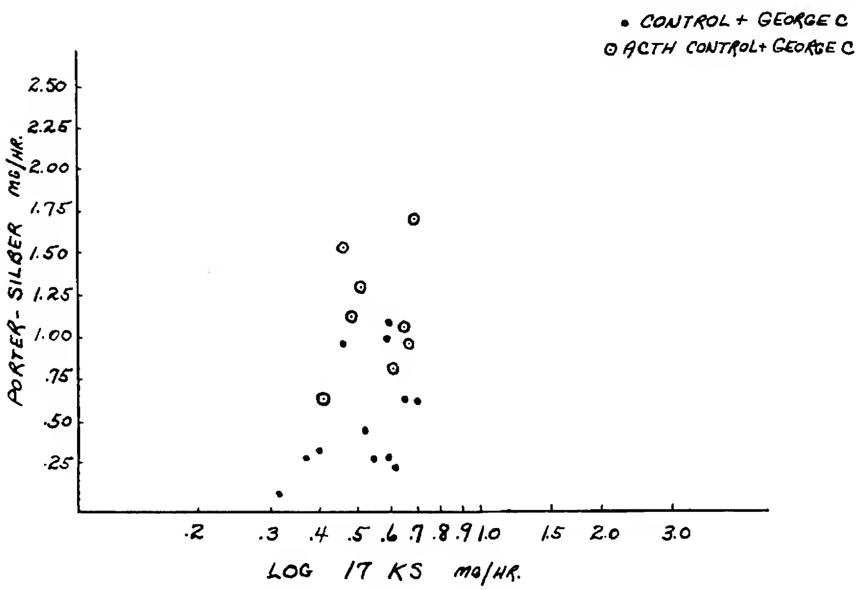

FIGURE 13. The distribution of samples considered as controls on which both 17-ketosteroids and Porter-Silber chromogens were obtained.

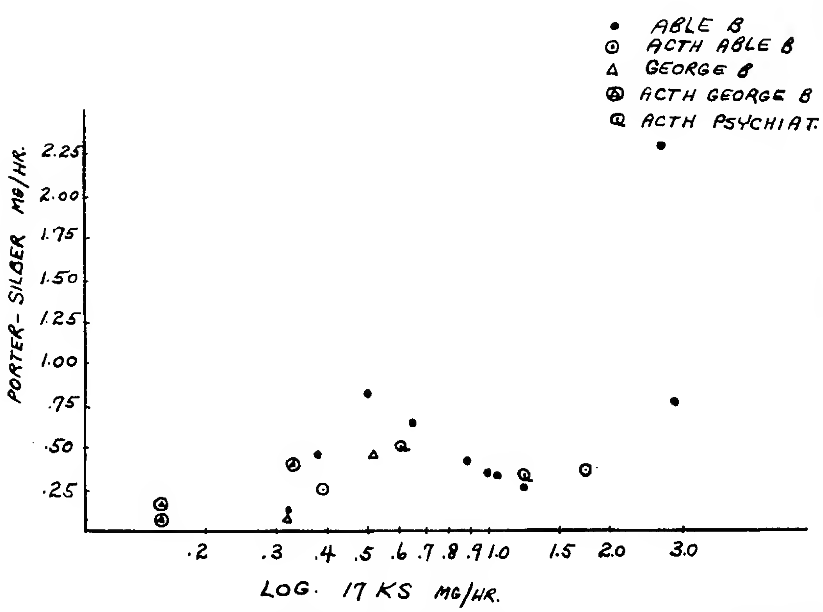

FIGURE 14. Scatter of the combat samples on which both 17-ketosteroids and Porter-Silber values were obtained.

Discussion

In the comparison of an acute stress against that of a chronic stress situation, a large number of indices indicate that the biochemical

status, or say biochemical profile, of a chronic battle situation is quite different from that of the acute. Where, in the acute state there is an indication of increased steroid output with increased protein catabolism, we find that in the chronic state (as far as the steroid measures are concerned) there is a dulling of the adrenal cortical function and no protein catabolism. However, it should be clear from the electrolyte data observed in the chronic stress situation after ACTH that the adrenal is not *completely* non-responsive; it is non-responsive as far as 17–KS and P–S are concerned, *but it does respond to ACTH where some hormone apparently related to the electrolyte function is stimulated.* It may be inferred that whatever hormone is being stimulated after ACTH (acting on the electrolytes) in the chronic group, these hormones are not the compounds detectable in 17–KS titer or in the P–S titer. In the pre-ACTH psychiatric group we see that 17–KS and the P–S indicate a lower adrenal cortical function level, but with some degree of electrolyte action present. Furthermore, when ACTH is given in the psychiatric group, there is a marked 17–KS response, *but the P–S is not very great*, as a matter of fact it is clearly less than normal. The electrolyte response is very sharp. The lowest electrolyte ratios are observed in the psychiatric group. Reviewing the data, then, each particular group, namely, the controls, the acute group, the chronic group and the psychiatric group, has a different "biochemical profile" and can be differentiated one from the other (table 4).

Table 4. Summary

Control data		Acute	Chronic	Psychiatric
Urine				
17–KS	0.64 mg./hr	(+)	(−)	(−)
P. S. Chrom	0.51 mg./hr	(+)	(−)	(−)
Na/K (molar)	3.0	(−)	(+)	(−)
Urea	450 mg. urea N/hr	(+)	n . . .	(−)
Uric acid	30 mg./hr	(+)	n . . .	n . . .
ACTH				
17–KS	(+)	(++)	(−)	(++)
P. S. Chrom	(++)	(−)	(−)	(−)
Na/K	(−)	(−)	(−)	(−−)

As far as the consequences to individuals having these various profiles are concerned: (1) The acute stress pattern is in favor of the individual, especially with respect to the possibility of an added insult to the organism such as a physical wound. The organism here has its

adrenals quite responsive. The glands are alert, and in case of any physical injury, the organism can very readily handle the result of physical wounds, such as loss of blood, etc. (2) In the chronic stress situation this is not the case. The individual's general physiologic condition indicates that with an added stress, such as a physical wound, the gland may be unable to handle its role in protecting the organism. The adrenal seems to be non-responsive, especially with regard to C 21 compounds. These are the compounds (F type) which are very important in resistance and adaptation to stress.

In the psychiatric group we find that there is a low 17–KS output and a low P–S in the pre-ACTH, but in the post-ACTH values there is a marked response of 17–KS. This marked increase in 17–KS, with the more or less feeble P–S reaction, encourages us to make the following inference: Either the compounds in this particular group are not C 21 in their origin, but C 19, or the C 21 compounds are rapidly converted to C 19. The C 19 in general are mostly androgenic in character and do not have a protective effect in a stress situation. Furthermore, since the steroid excretion is low in the psychiatric group even though the individuals showed marked emotional display and apparent stress, the pituitary possibly has been blocked and is unable to secrete normal amounts of ACTH. We may make the inference that in all probability increased adrenalin secretion could be responsible for this blockage. Thorn has shown that a continued infusion of the adrenalin does cause a blockage of the pituitary-adrenal axis. Adrenalin metabolism in conjunction with adrenal steroid metabolism is an area of study which should be investigated thoroughly, especially with respect to psychiatric breakdown.

As plausible as these points seem, the final proof of these various statements will depend on the chromatography of 17–KS, where the individual steroids will be separated out and quantitatively analyzed. We are getting to know to a great extent what the precursor of each compound (17–KS) in the urine is, and in this way can give a quantitative estimate of the various steroids presumed to be secreted by the adrenal glands.

A Final Speculation. From the data the following hypothesis may be offered. The adrenal gland on the first impulse, that is, in the first stages of stress, produces compound F (C 21) in large amounts. (It does produce some C 19 as well.) However, as the stress continues, we find that either the organism ceases to produce C 21 type of compound and produces in majority C 19, or that C 21 compounds are converted to C 19 more rapidly. These phenomena could have purposive explanations. (1) Since C 21 compounds (such as "F") are catabolic, it is clear that if the catabolism continued over a long period of time the organism would lose considerable nitrogen and deteriorate into a meta-

bolic disturbance simulating overdosage of "F." However, with the switch from C 21 to C 19 types (and these compounds are anabolic in their general metabolic effect) we find here a feed-back mechanism, where the excess protein catabolism is now counteracted by the steroids of the C 19 type which are anabolic, whereby the organism now is better able to protect itself. (2) If "F" were produced in excess over a long period of time, it would block the pituitary. The testing of this hypothesis will depend in great measure on the chromatographic results which should be completed within 6 months.

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CARE OF THE BATTLE CASUALTY IN ADVANCE OF THE AID STATION*

RUSSELL SCOTT, JR., M. D.

A review of the statistics dealing with the battle casualty in past wars has thrown increasing attention upon the extreme importance of the medical care given the wounded soldier during the first few hours after wounding. The mortality rate of the battle casualty after admission to a fixed hospital has fallen from 17 percent in World War I to 5 percent in World War II to 1.7 percent in the Korean War. In spite of these encouraging statistics, one out of every four wounded soldiers dies. The ratio of Killed in Action to Wounded in Action has changed very little since the First World War. The mortality rate at division and particularly battalion level has not paralleled the fall in the hospital mortality. For this reason, improvement of all facilities that speed the casualty to resuscitation and that bring resuscitation as far forward to the casualty as possible should be continued. In particular, intensive effort should be directed to the casualty in the most forward area.

To realize these aims it is of the utmost importance to appreciate what the *optimal care* of a battle casualty *can* and *should* consist of, under what conditions optimal care has been demonstrated to be possible, and what policies in training and supply must be adopted to insure the best care under any set of circumstances. It is necessary also to appreciate that variations in weather, terrain, tactical situation, efficiency of supply, etc., sometimes render optimal care difficult, but not impossible. We must therefore strive to modify our care as circumstances permit in order to give the best care possible at all times. As simple as this might appear, there is usually a significant delay in improving our care as circumstances allow. In order to have optimal care it is necessary for us to have a clear idea of what the optimal care of a battle casualty should be.

Before we go into the specific first aid procedures, let us formulate the broad aims and objectives of the early phase of resuscitation.

The broad aims and objectives of resuscitation are first to save life, then save limb and, at the same time, do the most good for the greatest

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number of casualties. To achieve these objectives we must understand the pathology of trauma so that from this knowledge we may emphasize the measures of resuscitation that are of *real* importance in saving life and limb.

Briefly, four major phenomena threaten life following wounding.

1. *First, and most important, blood is lost* and continues to be lost, not only to the exterior but into the damaged tissue at the wound or fracture. With blood loss there is progressive decrease in blood volume, fall in cardiac output, fall in blood pressure, decrease in renal blood flow and decrease in oxygenation of tissue.

2. *Tissue is damaged.* With tissue damage specific organs and systems are damaged, the media for bacterial growth are produced, and the latest laboratory work indicates that toxic products may be released from the damaged tissue and have a general systemic effect which in itself may cause death.

3. *The defense against bacteria is broken*, wounds become contaminated and bacterial evasion of the tissues and of the blood stream may occur.

4. *Mechanical defects may develop*, such as blockage of the airway, hemothorax, pneumothorax, cardiac tamponade or increase in intracranial pressure.

It must be understood that all of these four processes are *progressive, synergistic*, and *will continue* until measures are instituted to slow them down (first aid) and finally correct them (definitive surgery). As long as these processes are in motion, the casualty continues to deteriorate. In general, the intensity of early therapy and the time lag before the processes are finally brought to a halt determines the outcome of each casualty.

Aims of Resuscitation. It is important to appreciate that "resuscitation" includes the whole process of slowing down and stopping the pathological processes set in motion by wounding; first by simple local means, secondly by plasma or blood replacement therapy, and finally by operative intervention at the surgical hospital. In its complete sense, first aid in the field and surgery at the surgical hospital should be considered integral parts of resuscitation.

The specific aims, then, of resuscitation include:

1. Prevention of continued blood loss.
2. Prevention of additional tissue damage.
3. Prevention of additional bacterial contamination and suppression of bacterial growth.
4. Replacement of blood volume deficit.
5. Prevention or correction of mechanical defects in the cardiorespiratory and central nervous system physiology.
6. Relief of pain.

7. The removal of damaged tissue and repair of specific organs.

Again, the level or echelon at which each of the above measures may be carried out will depend upon many variables: the weather, tactical situation, terrain, efficiency of supply, and the ability and attitude of the medical personnel involved.

It should be obvious from this discussion that neither "first aid" on the battlefield nor surgery at the surgical hospital can be separated from resuscitation. The whole process of resuscitation should be considered to be an integrated program, beginning with first aid in the field and ending with surgery at the surgical hospital. We all know that military surgery is not just civilian surgery carried out in a tent; likewise, we must appreciate that combat first aid is not Boy Scout first aid carried out on the field of battle. If we are to lower the present battle mortality of 25 percent, every effort must be made to make the initial phase of resuscitation prompt, intensive, exact and thorough. One oversight or break in technic may well cost a life because of the long time lag involved in evacuation.

It would be impossible with the time and space allotted even to outline a complete course in first aid. The following section deals with the first aid measures believed to be the most important.

Optimal resuscitation begins with the aidmen in the field who attempt to slow down or stop the basic pathological processes that have been set in motion by wounding. This is done by initiating the aims of resuscitation.

1. *Prevention of Continued Blood Loss*

a. Pressure Dressings and Pressure Points. The vast majority of bleeding wounds can be controlled by the application of a pressure dressing. In addition to the pressure dressing, the patient may be instructed to add additional pressure. In most instances bleeding can be controlled by such measures.

b. Tourniquets. When a pressure dressing has proven to be unsatisfactory for the control of hemorrhage, a tourniquet should be resorted to. I use the word "resorted" advisedly, for the necessity of a tourniquet should occur only infrequently. It is of the utmost importance that all aidmen be well grounded in the use of the tourniquet. Often the tourniquet will not be applied correctly so that hemorrhage is not completely controlled, or the tourniquet may slip and bleeding recur so that a casualty will bleed to death while on the way to the aid station.

During cold weather an extremity with a tourniquet applied is unusually susceptible to freezing and gangrene formation. During the freezing months the aidmen and surgeon should be unusually careful

not to apply a tourniquet unless it is absolutely necessary and should do so only when repeated efforts to control hemorrhage have failed.

Once a tourniquet has been applied, any member of the medical team removing that tourniquet should exercise extremely good judgment, as bleeding may recur after the patient has passed through that period of observation. The removal of a tourniquet in cases where followup observation is impossible, such as during the period of evacuation, is extremely hazardous and should be avoided. The untimely removal of a tourniquet with recurrent hemorrhage, even when recognized and immediately stopped, has been shown to be serious. On occasion this error has thrown a casualty back into shock from which he could not be revived. However, when safe, the removal of a tourniquet reduces the chances of the casualty's losing an extremity. In casualties with extensive tissue damage where the need for amputation is obvious, the tourniquet can and should be left in place to avoid any chance of additional hemorrhage. This decision, however, should be made only by a medical officer.

c. Immobilization. Splinting of a fracture is of real assistance in preventing further vascular damage near the fracture site, and thereby prevening additional blood loss, both to the exterior and into the damaged muscle. Immobilization of any portion of the body which has been wounded is a sound principle to observe in order to decrease the chances of recurrent hemorrhage. Should an arm or leg be wounded, it is advisable to instruct the patient not to use that extremity until a location has been reached where complete resuscitation is possible should bleeding recur.

2. *Prevention of Additional Tissue Damage*

a. Splinting of Fractures. The proper application of a splint is the single most important factor in preventing additional tissue damage. Inadequate splinting, rough evacuation, or inadequate instructions to the patient as to how to manage himself during the period of evacuation, may result in additional tissue damage at the fracture site. The importance of prompt and adequate splinting cannot be overstressed. We should continue the motto of "when in doubt, splint them where they lie."

b. Immobilization of Any Wounded Part. Regardless of location, with or without fracture, it is also important to impede further tissue damage. If a missile should be lodged in a leg and a casualty is allowed to walk, the metallic fragment may well produce additional tissue damage or hemorrhage. Every wounded casualty should be instructed not to move the injured part for fear of producing additional tissue damage. If the casualty is disoriented, measures should

be taken to restrict movement of the wounded part. Should a leg have extensive muscle damage, a splint will do no harm.

3. *Prevention of Additional Contamination and Bacterial Growth*

a. An adequate dressing should be placed on the wound as soon as possible. By adequate is meant a dressing that is large enough and thick enough to protect the wound in its entire extent. Often more than one of the conventional dressings will be needed.

b. Antibiotic therapy in the field is also desirable under certain circumstances. In outpost positions, during assaults, or in any tactical situation where the casualty cannot reach the aid station until 4 or 5 hours or longer after wounding, antibiotic therapy by the aidman in the field is most desirable. This practice can be carried out with minimal effort by the use of penicillin syrettes. Antibiotic therapy at this early time is not only important in suppressing bacterial growth at the site of wounding, but also may be of particular value to casualties with abdominal wounds where the peritoneal cavity has become contaminated with fecal matter. Recent work indicates that in such cases bacteria may enter the blood stream and be deleterious to the patient's condition. Dressings, once applied, should not be removed so that wounds are exposed by the "look-see procedure" to satisfy the curiosity of the aidman or battalion surgeon. In the absence of continued bleeding or severe pain, removing the dressing to look at the wound accomplishes nothing and increases the chances of further contamination or hemorrhage. The unofficial policy or habit of looking at the wound at each level should be abandoned.

c. Burns should be covered with *dry sterile dressings* at the earliest possible time. In many instances, because of the extent of injury, this cannot be accomplished before the casualty reaches the aid station. All personnel should be warned *not* to use Vaseline dressings at this early time. Adequate cleansing of the wound in advance of the surgical hospital is impossible, and the application of Vaseline dressings in the field usually contributed to bacterial contamination. A Vaseline dressing, however, is preferable to no dressing at all, and should be used rather than leaving the burn completely exposed during evacuation. The application of a dry sterile dressing in the field does not obligate the casualty to continued treatment by the closed method. At the surgical hospital the first aid dressing applied in the field may be removed and the patient treated by the open method if the surgeon. in charge so desires.

4. *Replacement of Blood Volume Deficit*

The replacement of a deficit in blood volume is second only to the control of hemorrhage in saving life. With the new plasma ex-

panders, found to be efficient in combating shock, the aidman has a relatively harmless and inexpensive agent with which to resuscitate more completely the battle casualty at an earlier time. Prior to the advent of the plasma expanders, when pooled plasma was used, many surgeons felt the risk of hepatitis was probably too great to allow many aidmen to use their own discretion in administering plasma therapy on their own. With the new expanders the danger of hepatitis has been eliminated.

During the winter months it was found difficult and sometimes impossible to reconstitute the dried plasma. The loss of this expensive agent through breakage of the glass containers sometimes accounted for half of the plasma allotted to a given battalion. In addition, the glass containers were bulky for use on patrol, and the process of reconstituting the dried plasma required valuable time. Plasma expanders are now available in a light plastic container which can be easily carried by the aidmen. Plasma expanders so prepared are light, nonbreakable, and can be kept warm under the clothing of an aidman prior to administration. Their contents can be given under pressure by manipulation of the bag or by placing the casualty on the bag to create pressure.

Also important is the more vigorous replacement of the blood volume deficit in the field of battle prior to evacuation. This is important for three reasons:

a. First, the patient will be brought out of shock earlier and what deleterious effects shock has on the casualty will not operate as long.

b. Second, the condition of the seriously wounded patient is improved for his journey to the rear, he is in a less critical condition, and his chances of surviving the litter carry are better. All of the casualties with multiple penetrating wounds of the extremities, peripheral vascular wounds and traumatic amputations in whom hemostasis has been established will be greatly benefited by vigorous replacement therapy shortly before and during the period of evacuation to the aid station.

The casualty with internal bleeding is another problem. Vigorous replacement therapy and delay to any extent should be reserved for an echelon where immediate surgical intervention is possible should abdominal bleeding continue or recur as the blood pressure rises to normal; in most instances this will be the surgical hospital. In the hands of a skilled, well oriented, mature aidman, certain types of casualties would be definitely benefited, however, by more vigorous resuscitation in the forward area before evacuation is begun. By vigorous resuscitation is meant the administration of 500 to 1,000 ml. of a plasma expander over a 10-minute period. A "delay" of more than 10 minutes by the aidman is probably not justified. I avoid the

use of the word holding. Any delay in evacuation, however, should be reserved for those patients in whom *complete hemostasis* has been established. *If any degree of hemorrhage* continues, it would be unwise to expect an aidman to have the clinical judgment required to make a decision as to whether a patient's evacuation should be delayed for more vigorous resuscitation. If there is any question about continued hemorrhage, intravenous therapy should be started and a speedy evacuation to the aid station begun.

Whole blood therapy, which was shown to be practical in the aid stations under certain circumstances, is probably not practical in advance of the aid station, at least in the hands of the aidman. As a rule, it is usually impractical to give more than 1,000 cc. of an intravenous solution to a patient before he reaches the aid station and plasma expanders can be used without reservation in this amount.

c. Finally, it is important to recognize that certain types of wounds will eventually be accompanied by clinical shock unless intravenous therapy is instituted early. Such injuries as traumatic amputations and large evulsing wounds will eventually require intravenous therapy. Early intravenous therapy in such patients may well prevent clinical shock. This is the third reason that casualties will be benefited by intravenous therapy before and throughout the period of evacuation to the aid station.

5. *The Prevention or Correction of Defects in Cardio-respiratory Physiology*

At the time the battle casualty is initially examined, an effort should be made to determine whether the patient has signs of respiratory difficulty. If the patient has a sucking chest wound, this should be immediately closed with a Vaseline dressing. Many battalion surgeons instructed their aidmen to have the casualty exhale completely an instant before the Vaseline dressing is applied. This will force the major portion of free air out of the thoracic cavity thereby reducing the "dead space" caused by the free air within the thorax and will result in a larger vital capacity following closure of the chest wound.

The patient should be examined about the face and neck for wounds. If there is partial occlusion of the airway, this may be relieved by manipulating a shattered larynx or positioning the head in a particular manner. Instructions to the patient concerning how to hold his head or how to lie on the litter may be lifesaving during the period of evacuation. With bleeding about the nose and mouth, the patient should be instructed to lie in a manner that will allow the blood to drain to the exterior and not pass into the throat and cause aspiration and suffocation. The treatment of a hemothorax or cardiac

tamponade is beyond the ability of the aidman and should be reserved for a medical officer.

6. *Relief of Pain*

a. Immobilization of the wound is one of the greatest factors in relieving or preventing pain. This may be accomplished by splinting in the case of suspected or known fractures and by instructions to the patient as to how he should prevent movement of a wounded part during evacuation.

b. Reassurance and explanation to the patient is often beneficial. Many casualties expect pain, or in the excitement of battle, a fear of death or deformity actually magnifies in their own minds the amount of pain they are experiencing. A simple explanation that their wounds do not threaten life or limb and that a small amount of pain can and should be tolerated will quite often give gratifying relief to the casualty.

c. Morphine Therapy. Several known facts should be taken into consideration by the aidmen before administering morphine. These facts are:

(1) *A very small percentage of battle casualties actually have pain severe enough to warrant morphine therapy.* This is particularly true of casualties in shock. Patients in shock may be restless, hyperactive, and appear disoriented. The untrained will interpret this as a response to pain when the reaction is actually on the basis of cerebral anoxia. As stated, a large portion of the patients who claim to have pain are merely anxious and can be relieved of this anxiety by adequate psychotherapy founded on mature judgment of a sincere and well trained aidman or surgeon.

(2) *Morphine may be deleterious* in certain types of casualties.

(a) *Casualties with head wounds* should not receive morphine because morphine can alter the neurologic response of the casualty and make physical examination and evaluation before operation difficult.

(b) *Patients with chest wounds* and impaired respiratory physiology may have slowing of respiration and additional difficulty with adequate oxygenation of their blood.

(c) *Patients in shock* with poor peripheral blood flow may accumulate morphine in the peripheral tissues and receive an overdose once shock has been combated and adequate tissue profusion is restored.

(3) It has been clearly shown that a dose of one-sixth to one-fourth grain is as effective in relieving pain as a one-half grain dose and has less side effects.

(4) *Morphine may cause nausea and vomiting*, which can be deleterious to the patient.

(5) *Morphine may increase the hazard of anesthesia.*

In view of these facts, a real consideration should be made before morphine is given and any aidman administering morphine should have a thorough understanding of the indications and hazards as well as contraindications to morphine therapy. Many capable medical officers and civilian consultants feel strongly that the Medical Service should recall the one-half grain morphine syrettes and replace them with one-fourth grain syrettes.

7. *Transportation and Protection from the Elements*

It is important for all personnel dealing with the battle casualty to appreciate that exposure to the elements is deleterious to the casualty. It is important that adequate numbers of blankets (four to five) be available when a casualty is to be transported outside of a heated vehicle during the winter months. This can be made possible by instructing all members of a litter team to carry one blanket in addition to their normal load while on patrol or during an assault.

It is also important for all members of the medical team to appreciate that movement of the casualty is often deleterious, particularly while a patient is in shock. We should abandon the motto that "the shortest litter time is the best litter time" and put in its place "the smoothest litter carrier is the best litter carrier." This is particularly true after bleeding is controlled and intravenous therapy has been started when the need for speed is not urgent. It was observed at the Mobile Army Surgical Hospital that the movement of casualties from the preoperative ward to the x-ray table, not 50 feet away, can cause some patients to go back into severe shock. In two cases this resulted in death. The concept of preparing a patient for evacuation and then carrying out a smooth litter evacuation must be well understood by all members of the Medical Service.

The evacuation of casualties with head injuries is an individual problem. The ease of movement is more important following head injury than in any other injury. It was the feeling of some neurosurgeons attached to the Mobile Army Surgical Hospitals that a patient with an open head wound, received during the hours of darkness when helicopter evacuation was impossible, had a better chance to survive if he were held at the aid station until dawn to be evacuated by helicopter, rather than have a traumatic evacuation via ambulance. Once evacuation is started, the patient with a head injury should be positioned on his stomach to prevent aspiration should he vomit.

A smooth period of evacuation is not only important for the "general condition" of the patient in shock or with a head injury but, as stated, prevents additional tissue damage in extremities that have fractures. In dealing with problems of evacuation, it is the duty of the battalion surgeon to be ever alert for means of improving the speed and ease of evacuation from the fields of battle or in taking resuscitation to the casualty. This may be done in a number of ways.

a. By securing additional litter teams from labor pools of indigenous personnel.

b. By requesting additional vehicles, such as tanks and armored cars, to be used to pick up casualties under enemy fire.

c. By requesting that the battalion commander have litter trails or tramways constructed where indicated.

The construction of a "forward aid station" on the main line of resistance has enabled a medical officer, without unnecessary risk, to advance and set up an aid station on the main line of resistance in bunker positions. The bunkers are constructed to accommodate six to eight litters of patients and are usually within easy access of any portion of the battalion sector. In addition to this forward aid station, some battalions developed the concept of a "mobile aid station." The mobile aid station group usually consisted of the battalion surgeon or assistant battalion surgeon and two to three aidmen from the aid station. It was their function to move forward of the main line of resistance and meet incoming patrols with casualties or to move laterally to concentrations of casualties who did not have easy access to the forward aid station. In one sector a ¾-ton truck was converted into a heated, lightproof compartment and could be dispatched to any area night or day for the reception and treatment of wounded under adverse weather conditions. This was of great value on winter nights when a message was received that a number of wounded would arrive at a specific location distant from and inaccessible to the forward aid station.

Within the aid station more aggressive resuscitation by the medical officer should be carried out. To mention but a few examples: An intravenous cutdown may be instituted to insure that intravenous therapy will not be interrupted in a critically injured casualty; thoracentesis can be carried out to relieve a mediastinal shift; closure of sucking chest wounds, tracheotomy and intensive blood replacement therapy may be carried out at this level. These procedures will be discussed under the section on resuscitation within the aid station and details will not be given at this time.

A brief consideration of the supplies and equipment required to carry out effectively the aims of resuscitation is in order. Only the

equipment of the aidman and aid station pertinent to the care of the battle casualty will be considered.

An aidman should have available the following equipment:

1. Aid bag.
2. Tourniquets—either rubber or strap, probably two to three in number.
3. Carlyle pressure dressings with supplemental ace bandage, roller gauze and adhesive tape.
4. Arm sling.
5. Morphine syrettes (gr. ¼).
6. Penicillin syrettes.
7. Scissors.
8. Plasma expanders in plastic containers.

Such items as bandaids, merthiolate, hydrogen peroxide, cough syrup, APC's and swabs were found useful but not essential.

Within the aid station certain items are essential for adequate care at this level:

1. Adequate light—flashlights or Coleman lanterns.
2. Tourniquets, hemostats, Carlyle dressings and ace bandages for the control of hemorrhage.
3. Thomas lantern and wood splints with roller bandage for proper immobilization.
4. Scalpel, hemostats, suture material for performing a venous cut-down or closing a sucking chest wound.
5. Tracheotomy set.
6. Several 100 ml. syringes with No. 15 and No. 18 gauge needles to perform thoracentesis.
7. Procaine in sterile ampules for immediate injection.
8. Morphine in syrettes.
9. Penicillin in syrettes.
10. Tetanus toxoid.
11. Plasma expanders in plastic containers for administration under pressure if needed.
12. Sphygmomanometer and stethoscope.
13. Oral airway for unconscious patients.

The physical setup of the aid station will vary greatly depending upon the tactical situation, time available to construct the aid station, casualty flow and weather conditions.

In general, one should select a site for constructing an aid station which will give the surgeon adequate room to move as freely as possible from patient to patient. When the casualty load is heavy, it is advantageous to have the aid station divided into areas: a receiving area for sorting, a shock area, a splinting area and an area for patients waiting evacution.

Another important consideration of the aid station is protection from the elements. This is essential for the wounded casualty. When the tactical situation is fluid, a house or tent will suffice; when the line becomes stable, a tent which has been "dug in" or a large bunker is satisfactory. As stated, on occasion a closed, heated, ¾-ton truck may be used as a mobile aid station.

Conclusion

In conclusion, we may say that any significant reduction in battle mortality will be made by saving lives now lost within the battalion.

Most of the improvements and improvisions which increase the excellence of early care will be made possible through an understanding by the battalion surgeon and his aidmen of the ultimate goal of resuscitation and the role they play in achieving this goal. For a team to succeed, each member must have a clear understanding of the final objective.

Our training must stress the broad scope of resuscitation so that each member, both officer and enlisted, will realize that his actions play a vital role in the outcome of each casualty.

It is of the utmost importance that all members of the Medical Service and all members of the tactical units recognize and appreciate the great challenge placed on the aidmen and the battalion surgeon and be willing to support these individuals. No other members of the Medical Service are called upon to render unsupervised medical care to such a critically injured group of patients as are the battalion surgeons and aidmen. We must all recognize the need for the best trained men in the most forward area where the greatest test of ability is made and orient our policy and training to achieve this end.

EMERGENCY TREATMENT AND RESUSCITATION AT THE BATTALION LEVEL*

Major Meredith Mallory, Jr., MC

1. *Introduction*

In discussing emergency treatment and resuscitation practiced at battalion level, a breakdown of casualties into three general groups is helpful in defining our problem. These are: Group I—those killed outright or severely wounded past any help, Group II—severely wounded requiring continuous medical support and supervision, and Group III—those requiring minimal attention until they undergo definitive surgery. Group I is fairly sharply defined and is important medically only in that hopeless cases during heavy casualty loads must not be allowed to distract medical attention from the more fortunate who can be helped by it. The example given later illustrates how this might happen. The medical effort expended on Group II is justified primarily by the moral obligation to prevent loss of life. The salvage value of these casualties is limited for direct military purposes, but of considerable importance to the gross national output; especially when we contemplate the heavy financial obligation assumed by the Government in the event of mortality.

Group III represents the source of greatest return for medical man-hour expended. It is in this category that the human machine is repaired and the man returned to the duty for which he has been so expensively prepared. Although this is obvious to all and is implicit in the motto of the Medical Service, we sometimes partially lose sight of its immediate and direct consequence. This is that our medical capacity must satisfy the requirements of Group III category before any other with the exception of basic lifesaving measures necessary in Group II. This distinction must constantly remain in front of us if we are to tackle tomorrow's medical problem with the economy mandatory for all on the logistical team.

Groups II and III will tend to merge; indeed it is the primary aim of our forward care to preserve those in Group II until surgery is available (or else, by proper measures, such as tourniquet and splints,

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bring them out of Group II severity to the Group III level. Once a casualty is determined to be in the Group III class he then is promptly passed on to rear medical installations with but minimum treatment in the aid station.

The numerical proportions involved in these groups vary from war to war and battle to battle; however, an order-of-magnitude for the Korean war can be given. Roughly, out of 100 casualties, 25 will fall into Group I, 8 to 10 in Group II, and the remainder in Group III, with a number of the latter being borderline Group II. It is Group II, about 10 percent of all casualties, which composes almost the entire demand for forward medical care. Moreover, a brief look at casualty statistics by branch of service shows that the infantry is the major contributor, which means that forward medical care is essentially a matter of infantry support.

We will now go to a brief description of the circumstances in which forward medical care operates and the technics employed.

2. *Physical Factors of Battle*

Misunderstandings arise as to what should or should not be done in the infantry battalion aid station because of lack of consideration for the tactics involved. Table 1 portrays a concept of the variables which affect organized battle and its logistical support. Each combination of these variables forms a different circumstance occasioning great variation in the quality and quantity of medical care permitted in the aid station. It should be noted that the farther forward in battle the greater the impact of these variables on medical or other operations. To illustrate, the Korean war was fought under all three types of maneuver, in mountainous terrain, in generally temperate to cold weather, without analyzing each possible combination. It follows from the above that what should be done in the aid station cannot be stated inflexibly but will consist of doing a maximum number of desirable procedures according to limitations of a given situation.

Table 1.—Variables Affecting Logistical Support of Combat

Maneuver	Medium	Climate
Forward operations	Jungle	Very cold.
Retrograde operation	Desert	Cold.
Static operations	Mountain	Temperate.
	Plains	Hot, Dry.
	Airborne	Hot, Wet.
	River crossing	
	Amphibious	

Types of procedures recommended for aid station practice appear in the following discussion.

3. *Technics*

a. Shock. Shock, actual or potential, in the aid station means only one thing, the administration of fluids. Blood is the solution of choice with the solutions of albumin-size molecules next. It is, I believe, universally accepted that plasma infected with hepatitis virus is definitely contraindicated when the synthetics are available. The administration of fluids is based on rapid clinical evaluation alone as neither time nor equipment will permit more detailed observation. For purpose of resuscitation clinical judgment is sufficiently accurate. The combat injured are usually dehydrated so that glucose and/or saline can almost always be given advantageously to those requiring intravenous therapy. Venesection and cannulation should be a matter of *routine* practice for all patients for whom continuous fluids in large amount will be required. The value of these procedures in easing the handling of such patients in the rear surgical installations is difficult to exaggerate. *Any* intravenous therapy, once started, should not be intentionally discontinued until the patient reaches hospital care. Medical officers, fresh to combat, are usually unaware of the drastic requirement for blood and fluids occurring in severe trauma. Perhaps this is due to the relative rarity of trauma in combat degree in civil life and the fact that experience in handling it is simply not available.

b. Splints, Bandages, and Tourniquets. These technics, properly applied, do most to elevate a patient's category from Group II to Group III.

(1) *Splints.* The factor of traction has been overemphasized in handling battle or ordnance-caused fractures, since, as severity increases, generally the traction requirement decreases. Rigid immobilization and protection of the injured limb is the primary consideration. Our present splints and technics are not entirely satisfactory in this respect. For instance, I have seen a considerable amount of unnecessary and harmful manipulation due to our inflexible, dedicated, and withal, rarely expert, use of the Thomas splint. The Navy plywood splint was very popular with battalion surgeons in my experience and a splint of this type as a supplement to the Thomas splint seems to be required.

(2) *Bandages.* Although bandaging is important, our approach to this technic has been and remains unrealistic. Bandages do three things: (a) provide hemostasis, (b) prevent dis-

turbance of the wound by foreign objects, and (c) prevent bacterial contamination. Of these, only hemostasis is important in battle. A bandage that secures hemostasis provides incidentally sufficient protection from foreign material and bacteria. In respect to bacteria, all battle wounds are grossly contaminated and remain so until débridement. Too much effort is wasted in procurement of and training in a complicated array of bandages and bandaging technics.

(3) *Tourniquets.* Application of adequate and timely tourniquets in battle is a vital essential at battalion level. Patients, whose wounds should place them in Group III often become Group II, and all too frequently Group I members through lack of an effective tourniquet. Present methods are time-consuming, inaccurate as to pressure exerted and often require excessive manipulation of the injured part (especially when applied by a single person). Self-application is virtually impossible. In the case of lower extremity wounds, which give rise to the most severe hemorrhage controllable by tourniquet, it has been my observation that too few doctors, much less their lay assistants, have a concept of the constricting pressure required about the thigh to abolish the flow of blood. Since the amount of blood lost after injury is probably related to time in an exponential fashion, most of it occurring the first few minutes, the tourniquet to be effective must be applied before the patient reaches the aid station. This requires that it be done in or very near the battle area. This further demands that the method be very simple and rapid and applicable by anyone—characteristics not possessed by the present means. Although we can improve application of tourniquets by increasing the training of the soldier, medical or other, this has two very undesirable features:

(a) It is only a partial solution of the deficiencies noted above.

(b) It will encroach on other more essential combat training.

We need, critically, a better tourniquet device.

c. *Points in Handling Specific Wound Types.*

(1) *Chest.* Penetrating wounds of the chest (sucking) must be sealed airtight by the first medical officer to treat the patient. Any means, even to application of bare adhesive strips over the wound, are permissible as long as a good seal is obtained. Rubber sheeting over the wound sealed with Vaseline is another method. Simple gauze bandaging is most often not effective. A few deep sutures through the wounds to approximate wound edges may be necessary and can be done in the aid station. Although but infrequently necessary, the medi-

cal officer in any forward medical installation should be prepared to perform chest aspiration using a large needle, three-way stop-cock and large syringe. An evacuated intravenous bottle may also be used to produce suction (evacuated by boiling a small amount of water in it and sealing while filled with steam). These patients, often short of breath because of the reduced respiratory volume, need encouragement probably more than any other casualty. Their symptoms frequently exceed the immediate criticality of their condition.

(2) *Abdomen.* Those with penetrating abdominal wounds require maximum rapidity in evacuation to definitive surgical attention. They should be retained in forward installations only long enough to support adequately the circulation for transport to the rear. Mortality on these patients varies directly with time-lag between wounding and surgery and is virtually 100 percent at 24 hours.

(3) *Central Nervous System Injuries.* Patients with these injuries require immediate evacuation to neurosurgical care. Spinal cord injuries, in general, require the most immediate surgery of any injury, if salvage of cord function is to be a possibility. The recommendations as to position of patients with spine injuries have always appeared equivocal and contradictory. For injuries caused by ordnance probably the best solution is to minimize movement and evacuate the patients in the position they arrive in the aid station, prone or supine.

(4) *Extremity Injuries.* Hemostasis should be secured by bandage and/or tourniquet. Fractures should be adequately splinted. In combined extremity and trunk injury it is imperative that hemostasis and splinting of the extremity wound be done properly so that the additive effect of the multiple trauma will be combatted and prevented from delaying early surgery. Extremity injuries, by themselves, should never occasion mortality except in the most unusual circumstance if adequate tourniquet procedures are available.

d. Sedation. Patients with fractures and uncomplicated soft tissue injury may have morphine until adequate bandaging and splinting are applied. It is contraindicated in chest, head and belly wounds for obvious physiologic and diagnostic reasons. The single dose should not exceed 0.25 grain (one-half syrette) and each dose *must* be accurately and clearly noted on the Emergency Medical Tag. Pain is very infrequently a significant factor in injuries seen at forward levels. In extreme cold the administration of morphine should be even further curtailed.

e. Antibiotics. The requirement for early administration of antibiotics is recognized by all and needs no further discussion here.

f. Triage. Selection of patients for type of evacuation (helicopter or ambulance) is essential, especially when movement and transportation are limited. The following wound types are listed in order of priority for rapidity of evacuation to surgical care.

Priorities for Evacuation

(1) Spinal cord.
(2) Uncontrollable severe hemorrhage (after blood and fluids have been started).
(3) Abdomen.
(4) Chest.
(5) Head.
(6) Extremity.

Time of wounding is also an important consideration in triage. A fresh fracture occurring just outside the aid station door does not have the necessity for immediate treatment that a 24-hour-old moderately severe soft tissue wound of the thigh does.

4. *Management*

In applying the technics above, in battle circumstances, to the three casualty groups specified, it is clear that efficiency will not be obtained without premeditation and organization. I would like, now, to mention matters of arrangement, equipment, procedures and training.

a. Arrangements. The aid station must be arranged to handle a large volume of wounded and not just to handle sick call or occasional patients. This arrangement should be as elaborate as is possible to devise in a given situation. It should provide for orderly flow and segregation of casualties in the station. Each person should know precisely his place and job in the casualty stream. Litter supports to place the litter at table height must be procured and the medical equipment laid out nearby to be readily available. A system must be devised with the battalion S–1 and S–4 to handle the stragglers, hangers-on and materiel that swiftly accumulate about the aid station in heavy fighting. Neglect of this item of arrangement can cut the effectiveness of an aid station by many times.

b. Equipment. The equipment presently organic to the aid station contained in Dispensary Medical Set, Field; Medical Field Set, Combat; and Medical Field Set, Supplemental Supply; is, in general, appropriate. Instruments to accomplish vein cut-downs, tracheotomies and chest aspiration should be immediately available. These can be made up in formal sets packaged sterilized or can be merely a collection of instruments requisitioned as needed in addition to that in the field sets. Refrigerators and electrical generators are very

desirable but are logistical problems. Iceboxes may have to be improvised for the storage of blood. In general, the more frequently the aid station moves, the less equipment it will carry. The best solution is to have a minimum of organic equipment and augment it whenever additional equipment is indicated. It is the province of the Division and Army Surgeon to see that all necessary and appropriate technics and materiel are employed in the battalion aid station.

c. Procedure. The basic principle of procedure is that the medical officer must not involve himself in anything that he can train someone else to handle. He must occupy himself with the severely injured patients, leaving the moderately injured to his assistants. As indicated above, he should be prepared to institute any emergency measure to save life, such measures to include thoracentesis, tracheotomy, venesection, and placement of deep sutures to secure hemostasis. In one case we moved an anesthetic machine from clearing station to battalion aid to intubate a head patient in respiratory arrest, the battalion surgeon and others administering artificial respiration for 1 to 2 hours while waiting for its arrival. The patient was intubated and moved 30 miles by ambulance to a MASH with anesthetist attending and survived the journey, although he eventually succumbed from his hopeless wound. It is difficult to be too radical in an aid station. Errors arose frequently from "too little" and never from "too much." We do not teach the handling of acute severe trauma well in our medical institutions, judging from results observed in Korea. Happily a short period of on-the-job training usually sufficed. Improved and more uniform treatment would result, however, if this problem were attacked earlier in our medical education.

d. Training. It goes without saying that training must be constant and unremitting from a short course for the doctor in division before he goes forward to become a battalion surgeon to the training he himself administers to his subordinates to enable himself to be free of the multitude of details of bandaging, splinting and sorting of the uncomplicated patients. The personnel replacement stream for medical officers should be liberal enough to allow for a short period of formal and on-the-job training in division. This time can be secured by cutting Zone of Interior training where much is taught that has limited value. Personnel assigned to division will have their life's total combat experience in the succeeding few months that they serve with that division. They need only be trained for this narrow restricted experience and a large part of it can be given in the division where specific points relative to local problems of medical support can best be emphasized.

5. *Personnel*

a. Officer. Two officers are required in each infantry aid station, either two MC's as with the Marines, or one MC and one MSC as in the Army units. In my opinion, the MC–MSC (or possibly Warrant) combination is best, provided this is utilized to make available battlefield commissions for qualified enlisted personnel from the aid platoons.

b. Enlisted. The enlisted medics (MOS 3666) generally available in Korea were of excellent caliber. In fact, one wonders if we do not invest too much capability in unskilled tasks such as litter bearing. The one emolument here, of course, is that litter bearers are then available to act as aidmen. However, by accepting lower-quality personnel it might be feasible from the standpoint of manpower economy to augment our present litter bearer units. Though the proportion of aidmen required may be open to argument it is certain that these people must be trainable to act with initiative and effectiveness by themselves in administering first aid. They must be able to bandage, splint, apply tourniquets and give fluids intravenously without supervision and assist in all the many other medical responsibilities of the aid station. Their present training is satisfactory except for a tendency to include too many technical nonessentials. Continued on-the-job training by interested medical officers should further technical education and can create some extraordinarily effective medical assistants out of many of these soldiers.

6. *Conclusion*

Our present theory and practice of medicine in the aid station is well conceived and effective in general application. We might seek improvement in detail as follows:

a. Devote specific attention to securing a better method of applying tourniquets.

b. Give specific instruction in medical school in battlefield and disaster emergency therapy and resuscitation.

c. Re-evaluate certain of our bandaging and splinting doctrines.

d. Reapportion training time of the medical officer so that a maximum occurs in the combat zone where his medical practice will be located.

e. Examine the feasibility of utilizing lower-quality personnel for the menial, non-technical jobs in medical soldiering in combat.

MONDAY AFTERNOON SESSION

19 April 1954

MODERATOR

John M. Howard, M. D.

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PROFESSIONAL CONSIDERATIONS OF PATIENT EVACUATION*

LIEUTENANT COLONEL DOUGLAS LINDSEY, MC

Any discussion on the implications of experience in the Korean war must be undertaken in an atmosphere of conscious, continued caution. In spite of how long and drawn-out an 18-month tour of duty felt to me personally, I still realize keenly that the Korean war offers only a fleeting espisode for historical analysis. This is not to say that generalizations cannot be made; they should be. We must continually develop, revise and supersede our policies, plans and procedures. But conclusions must be drawn only after sober, skeptical, philosophical reflection. Generalizations founded on the Korean war stand on a narrow base, and if the process of broadening and projection is not carefully done, the whole structure will topple under the stress of trying to fit it to a very slight alteration of circumstances. There is a tendency either to accept a single experience in Korea as setting the pattern for the future, or to ignore all of our experience there as invalid for future planning on the basis that it was so unusual or specialized as to be generally inapplicable.

I would like to quote just a few examples of hasty conclusions that have been drawn from experiences in the Korean war. At one time, a great difference between cold injury rates between two successive winters was quoted widely as heralding the effect of improved clothing and equipment, and improved leadership and discipline. Yes, these factors did vastly improve between the two winters, but *no* mention was made of the overpowering effect of the vastly different tactical situations: in the first winter we were fighting desperately, and moving often. In the second winter the lines were stable, the fighting much less severe, and shelter was more plentiful and better developed. This patent error was made in the face of the fact that a similarly fallacious conclusion was made in World War II, in comparing the rates for successive months of the winter of 1944–45 in Europe, and that error was later openly disclosed. Incidentally, the hue and cry over the rigors of the Korean winter obscures the fact that the climate

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at the 38th parallel is comparable to that of northern New England and that at the Yalu is no more severe than that of Montana.

I have seen the statement made, with relation to the difficult terrain and lack of communications in Korea, that the problems which we faced in Korea were different from those encountered in any previous operation. It is clear that the author of this statement is enthusiastic, and soundly impressed by his Korean experience, but just as clear that he did not participate in the campaigns in Burma, New Guinea or Italy, nor has he maneuvered in Alaska or trained in the Rockies.

I repeatedly hear officers returning from a limited tour of duty in a limited assignment in Korea extolling the virtues of "the way we did it in Korea" along with heated discussion and forceful proposals to the effect that this is the *best* way to do it, and the way it shall be done henceforth—all this without realization that the particular interval organization, or mission, or function, or equipment for the unit in question was designed by the responsible planners to fit particular circumstances, or was a frank expedient and improvisation, reluctantly accepted by higher headquarters to make the best of the limitations of a bad situation.

I have seen an official statement made that the bunker aid stations, during the static phases of war, carried heavy excesses of dressings, splints and plasma. Since frequent moving tends to shake a unit down and immobility tends to promote a buildup of supplies, this is an entirely logical conclusion in theory. Typical illustrative photographs of aid stations appear to lend impressive support to this thesis. Further, if the author of the statement had interviewed a number of battalion surgeons their testimony would have wholly supported him. But actually the aid stations were *not* carrying an excess and were even dangerously low in the basic supplies needed for support of battle casualties. At that same time I was concerned enough about the ability of the forward installations to support the initial phases of a push that I made a survey, based not on interview or observation, but on actual count. The cold fact is that the battalion surgeons did not *know* what their basic authorizations and requirements were, and I did not find a single installation whose supply of splints, dressings and plasma came up to the basic load, much less exceeded it. The static period promoted the acquisition or fabrication of fancy equipment and frills, but the low flow of casualties during most of the war promoted the acceptance of an abnormal baseline. As soon as there occurred a brisk flow of casualties, it was seldom regarded as "normal" to an "average" battle situation, but there was a tendency to scream for reinforcement in personnel, send in an immediate emergency requisition for supplies and emphasize the moving out of patients as

rapidly as possible, an emphasis on *transportation* at a certain expense to *treatment*.

The point of this last example is that whenever the factor under consideration is subject to objective comparison or quantitative measurement, such comparison or measurement should be made. When the matter is one of opinion, one should get as many separate opinions as possible.

Much of what I have to say will be prefaced by "I feel," "I think," or "I believe," since I alone stand responsible for the conclusions, estimates, and recommendations I present, and since determinations of degree of success or fortune and recommendations as to what things might have been done better, or how, are often matters of opinion. However, this presentation is based in great part on material developed for formal staff studies in Headquarters, Eighth Army. Most of it has been included in various official reports from that headquarters. It represents much careful, objective consideration. I feel that it meets The Surgeon General's injunction to all of us speakers that we offer thoughtful, documented analyses.

In exercising your caution and skepticism in appraising even my own material I ask you to remember—and I will remind you of it frequently—that during most of the Korean war the front was geographically stable. During that same period United States casualties were relatively light, with sporadic periods of heavy casualty flow, limited in time and limited in the sector and units involved. We were able to settle down, smooth out the rough spots and, generally speaking, offer custom-made, personalized professional service to every serious casualty. We will not be able to do this to the same degree in a moving situation, or in a situation with a sustained heavy casualty flow.

In particular, I feel that much of the specific medical research that produced the technical data which are to be presented to you in this symposium was vastly facilitated by the peculiarly favorable circumstances that existed in the latter 2 years of the war. Research, in all the branches of the Military, is following hotly on the heels of the combat troops, and some of the operations research actually goes on out in the combat squad area. The accomplishment of Army medical research teams was phenomenal. I am too conservative a pessimist to state that they could not have done as much in the face of heavy fighting and a moving front, but it would have taken a great deal more effort, inconvenience and administrative and logistic support to do so. In such a situation I think the pattern and orientation of research will change.

No matter how hot the battle and how rapid the maneuver, there is room for clinical research in the forward areas. What I have in mind

is the type of work that Jahnke and Hughes did in vascular surgery, and a great deal of the work of Artz and Howard (at least 70 percent of it) in which the laboratory element was minor. We need some of this research even farther forward: a number of men with broad surgical background, mature judgment, sincere interest and staunch heart—to go up and work with battalion surgeons, or as battalion surgeons, for extensive periods, then reflect and recommend on what they see.

If the surgical hospital is moving 2 or 3 times a week, 8 to 10 miles per move, I think you will find it rather difficult to carry out there any intensive technical research involving the more complicated laboratory determinations. If it is deemed essential to do so, the mission can be accomplished by reinforcing the host hospital with transportation, personnel and other support facilities. It would appear more feasible, however, to arrive at the same result by giving the team a permanent base more to the rear, feeding to it by air the patients, specimens or data collected and selected by the clinical members of the team working at the forward location.

The system of medical evacuation in Korea is familiar to most of you. It is basically the same as that of World War II and World War I. A medical soldier—the company aidman—accompanies the infantry platoon into combat. He administers emergency treatment on the field of battle and places the wounded man in a sheltered location, if possible, for somebody else to come and pick him up. He cannot linger long; he must keep up with his advancing unit. Casualties in the engagement may number 2 or 40 and the last of the number may be the one who needs him worst, or with the least delay.

Usually, the conditions of fire and terrain are such that the casualty is moved initially by the backbreaking method of litter carry, possibly with relay by surface vehicle. At the battalion aid station he is seen for the first time by a doctor, on whose professional skill the lives of the seriously wounded depend. No surgical hospital or general hospital can save a life that is lost at this station or in front of it.

After such treatment as is indicated at the battalion aid station the casualty is moved—practically always by a mechanical means of transportation, surface or air—through one or more field-type installations before reaching a true hospital. At the hospital he receives definitive surgical treatment and becomes more a "patient" than a "casualty." In this and successive hospitals the patient receives surgical care entirely comparable in quality and scope to that administered in civil hospitals, though slightly different in technic. The major difference is that his hospital care involves several separate hospital staffs in several successive locations. Some of the hospitals in the casualty evacuation system deal customarily only with strict surgical emer-

gencies. Others, though dealing with traumatic surgery, which in civil life is usually regarded as an emergency regardless of degree, receive patients of a deferred or lesser priority.

Professional considerations are vitally important throughout every stage of this process of moving casualties to the rear and treating them at the same time. However, based on the invitation of Colonel Stone, I have selected for emphasis certain specific points of direct professional interest. These are:

The importance of battlefield treatment.
The professional function of the battalion aid station.
The role of the clearing station.
The mission of the surgical hospital.
Patient holding operations.
Allocation and use of evacuation facilities in Korea.
The utilization of evacuation hospitals.

The Importance of Battlefield Treatment

It is difficult to emphasize sufficiently the importance of initial treatment on the battlefield. What the wounded soldier does in his own behalf, or what his infantry colleagues do for him; and what the company aidman does for a traumatic amputation or gaping wound of the chest, in the thick of battle, in dust and heat or in blowing snow—on these simple procedures depend life and death.

Major Mallory and Dr. Scott have already mentioned these things. I wish only to add my own emphasis and indicate that they are matters for professional concern. A slight improvement in the skill and judgment of the company aidman will save us more human lives than will the attainment of 100 percent perfection in the surgical hospital.

But this development of the company aidman and changes in the standard procedures for infantry first aid must be founded on professional considerations, and the stimulus will have to be provided by professional people. The line are generally satisfied with, or proud of, their aidmen. They extol their hardihood and sacrifice, and other rugged and simple virtues, but express rather little concern over their technical competence.

There are differences of opinion regarding the aidman, even regarding his basic position in the military scheme. Some feel that this man is an infantryman first, to be skilled in the rudiments of first aid as an afterthought. It is true that unless his knowledge of the craftsmanship of battle is adequate he will never reach the side of the subject of his ministrations, and true, also, that in many armies

he is a member of the loyal regiment of infantry, rather than a member of the Army Medical Corps. Even in our own United States Army Medical Service many feel that he is an inferior being in the medical enlisted field. This should not be. I can take any clever meatcutter, carpenter, or mechanic and develop him into a highly competent surgical operative assistant. Something more than that is needed in the company aidman. It takes men of intelligence, moral purpose and ambition, but, most of all, *judgment*, which cannot be developed by brief practice and study. We will not get men of this caliber until the professional people in the Army Medical Service realize their importance and support a degree of precedence for the selection, training, and assignment of them.

A word about the litter bearer, who links the company aidman with the battalion surgeon. He is still with us. He was not replaced in Korea by the helicopter, the tramway or the Korean Service Corps. In Korea the helicopter rarely operated forward of the battalion aid station. And even later, when the machine is plentiful, it will not customarily operate on the actual battlefield unless the character of battle has so changed that the infantryman is no longer on foot, nor in an armored vehicle. That time is not nearly at hand.

We tend occasionally to count the short time lag between the battalion aid station and the surgical hospital operating table, and to be smugly pleased without thinking of the time spent forward of the aid station. In a stable, permanently developed sector with tramway or jeep road to the top of the company hill this time is not greatly significant. Without these improvements, and depending on litter haul, the time span is tremendously increased, and the initial treatment, treatment en route and treatment in the battalion aid station are commensurately increased in importance. In virgin terrain in Korea a litter squad could be expected to make approximately 100 to 300 meters per hour in horizontal distance. Thus an aid station 500 meters away from the company on the hill is 2 to 4 hours distant. In special circumstances this time distance increases even more. In a night outpost action, a man wounded before midnight often will not reach the aid station until 1000 the next morning, and I know of one outpost in Korea that required (I am told) a litter haul that was 36 hours round trip. I accept this staggering figure as true, since I personally verified the fact that the litter haul from the *main* battle positions of each of the three battalions of the regiment was not less than 8 hours. These difficulties were not peculiar to Korea, and we will have the same problems in many of the possible battlefields of the future.

The Professional Function of the Battalion Aid Station

The professional considerations involved in medical service operations forward of the battalion aid station are not readily apparent to the outside observer, but the problems in the aid station itself are more orthodox and more familiar to you.

Here we have a graduate M. D., and we have equipped him well to perform professional resuscitation. Some of his professional capabilities have been outlined by Major Mallory and Dr. Scott. The physical appearance of his office may vary widely. It may be a hastily parked vehicle, with blankets, splints and a few opened chests. It may be a bunker, with electric lights, white sheets, a bubbling sterilizer and neat shelves of drugs and dressings. At any of these places we can do as good a tracheotomy or thoracentesis as on any university hospital pediatric or surgical ward. We can cut down on a vein and give blood under pressure. The distribution of blood to forward stations is something we did not have in World War II. It is an improvement in service we can keep up in the future, and is not to be considered a luxury made possible by the static situation in Korea, to be lost in the event of moving warfare.

In spite of these facilities, *professional* resuscitation was often neglected. And a lot of us are to blame. Through two World Wars and Korea we have passively sustained, or actively contributed to the discouraging misconception that the battalion surgeon is nothing more than a commissioned aidman. Many of these men believe that, and when they do believe it, they act it. With that attitude and the availability of the helicopter they become transportation agents and their activities there seldom exceed the changing or reinforcing of the dressing, the starting of one bottle of blood or dextran, and moving the patient out as rapidly as possible, almost first come first served. One too rarely sees a casualty retained in the aid station for intensive therapy to insure that he will stand the trip to the rear and not arrive at the surgical hospital dead or dying.

One of the best characterizations of the battalion medical officer (*1*) indicates that ". . . he must retain coolness and calmness and must show a near perfection of surgical judgment under the most adverse conditions. Surgical judgment is that indefinable but essential attribute compiled of just the right mixture of a stable nervous system, past surgical experience, common sense, and an ever-ready diagnostic ability." I am sure we all agree. Yet we persist in labeling the position one for MOS 3100: Medical Officer, General Duty. The people who hold this MOS are typically either lieutenants fresh out of internship, without advanced training, or general practitioners, also—too often—without graduate training. We persist in this even

in the face of a great scarcity of men of this MOS, and a great surplus of specialists of various sorts, who are better suited for the job.

By far the best battalion surgeons we had in Korea were the specialists who went into those jobs by reason of that scarcity and surplus. Of the battalion surgeons I knew well, the three best were a board-qualified surgeon, a board-certified internist, and a board-qualified obstetrician. We can use the untrained and inexperienced men in hospitals in the rear, where they can work and learn under supervision. The battalion surgeon stands on *his* experience alone, and we must have the best for the job. When the time comes in major mobilization that we do not have a surplus of residency trained men, we must provide the battalion surgeon with specialized military professional training to qualify him for this job.

One professional problem in battalion medical service that we have not squarely met is the question of just what is the function of the Lieutenant, Medical Service Corps, who is assistant to the battalion surgeon. Are we offering him as a "stand-in" substitute for the battalion medical officer? Surely not, with the limited training and experience that he has. When a battalion surgeon is killed or wounded or goes on leave the MSC officer does not succeed him; a medical officer replacement comes from the collecting platoon or the medical battalion. Is the MSC officer there as an administrative or managerial or tactical assistant? Surely not. This is a travesty against sound principles of management, a farce in the face of need for personnel economy, duplicating the functions of the platoon sergeant, and an insult to the everyday business judgment of the average practitioner of medicine.

There just is not enough administration in a battalion medical platoon to call for an officer to manage it and there are not technical or subprofessional duties appropriate to officer grade. Warrant officer? Perhaps, as the top rung of the enlisted field medical career ladder. But officer—no. This position appears wholly anomalous until we look to history for the explanation and find it to be not an anomaly but, now, a useless vestigial appendage. Prior to 1944 our Tables of Organization gave two medical officers to the infantry battalion: a Battalion Surgeon, and an Assistant Battalion Surgeon. It was considered that our medical manpower resources, even on our lush staffing of World War II, could not support both positions and one was reluctantly dropped. It was not that the job did not exist, but we did not have men to fill it. The Marines still have two doctors per battalion and I have not heard the incumbents of those positions complaining that their services were not needed, nor that one of them was primarily a platoon administrator.

In World War II the first group of Medical Administrative Corps (MAC) officers was specially selected and specially trained. Frankly, I learned a great deal about combat medicine from the second lieutenant, MAC, who was on the ground when I came in to take over as an Infantry Battalion Surgeon. This is both a tribute to his own ability and a frank appraisal of the sketchy nature of the training I had received in military medicine. The first group of MAC assistants included typically two types of men: oldtimers in the Medical Department, well versed in their trade, and commissioned as officers in the expansion of the Army; and others of less military experience, commissioned in the medical branch on the basis of paramedical civilian background. They received intensive training in advanced first aid, and went out with commendable enthusiasm to do their share in a major war.

These conditions do not pertain now, nor did they pertain during the Korean war. In the first few months in Korea, career Medical Service Corps officers—Adjutants, Registrars and Supply officers—went out from administrative positions in the Far East Command and substituted for the Battalion Surgeons and Regimental Surgeons that the Army did not have. As lieutenants, captains and majors they actually assumed the responsibilities of Medical Corps officers and carried out professional functions.

During the latter part of the Korean war, our typical assistant Battalion Surgeon was an officer on his first field assignment, with a few weeks of medical service training, after a direct commission on the basis of a bachelor's degree in anything from law to anthropology, or officer candidate school training in infantry or artillery. The former group could not be fully considered as officers, but only as commissioned technicians, and working at the moment out of their technical field. The latter group could be considered, at best, forced emigrants from the combat arms, and at worst, fugitives from a rifle platoon.

If we are going to train this officer sufficiently well to have him function as an effective medical assistant, we are going to have little time left out of a 3-year Reservist's career. Worse, we will be embarking on the treacherous policy of giving some appearance of accepting a second-rate class of physicians. Even if we gave the officer a great deal more training, it would be foolish to expect that he would render any technical or subprofessional service that could not be performed immeasurably better by a good sergeant with 6 years of experience in the Army Medical Service, and the latter would be performing the obviously legitimate function of a nonprofessional technical assistant.

The Medical Service Corps certainly cannot sincerely mourn his loss. A year or so of service in a position combining, in effect, the duties of a senior dispensary clerk and a medical technician is not valuable preparation for an ultimate position of great responsibility in the administration of a hospital, or management of a medical depot.

The type and extent of medical care offered within the battalion aid station has been admirably presented by Major Mallory. I have been asked by Colonel Stone to discuss the professional considerations involved in evacuation of patients *from* the battalion aid station. They can be rather simply outlined:

1. The battalion aid station is no place to maintain a ward—the patients should be returned to duty or moved on as soon as they can travel.
2. No patient should be evacuated who has not received the benefit of treatment which is available at the aid station:
   - *a.* Bleeding should have been stopped, unless stopping it requires an actual operative procedure.
   - *b.* A patient in shock should be improving, or stabilized, unless it appears clear that treatment beyond the facilities of the aid station is the only means of improvement.
   - *c.* A major fracture of a long bone should have been adequately splinted.
   - *d.* The basic mechanics of respiration should be intact.
3. No patient should be evacuated unless he is in condition to survive the journey under the specific conditions he faces; and, conversely, the sequence and means of evacuation should be a matter of specific priority and individual selection.

These criteria admittedly seem trite. Let me assure you that they are violated often enough to require continuing supervision to insure their enforcement.

None of these considerations require elaboration except possibly the statement that the battalion aid station has no holding ward. I reconcile this with the accepted handling of a mild combat-induced anxiety state by choosing to regard these men, held overnight for a little rest and reassurance, not as true patients. The further forward they are retained, the better the result. This principle does not hold so strongly in the case of minor medical illnesses, and a more appropriate place to hold these patients for treatment and recovery is the regimental collecting station.

A restriction against holding patients at the battalion aid station in no way impedes the battalion surgeon in his mission of preventing the loss of military manpower of the battalion, or detracts from the importance of that mission. He should be able to treat promptly,

and immediately *return to duty*, a significant proportion of the wounded who reach this station. Not every little wound requires a formal débridement, and rear hospitals see too many utterly trivial wounds for which a band-aid would have been sufficient treatment. Occasionally we may err, and cover with a dressing and dismiss with reassurance a trivial scratch which actually is a significant wound of entrance. Conscientious diagnosis and judicious followup will make our misses in this type of case actually more rare than they are in traumatic surgery in civil life.

Evacuation from the battalion aid station is typically by two means: surface ambulance and helicopter. Evacuation *from* the aid station by litter bearer was almost never required. Physical conditions usually permitted the ¾-ton ambulances of the division medical battalion to be used as far forward as the battalion aid stations, but tactical considerations or formal policy of the division or regiment often precluded their use ahead of the regimental collecting station, in which event the surface vehicles utilized were the litter-jeep ambulances of the regimental medical company. This vehicle is an abominable improvisation retained in service because of our failure to develop anything better. The six-wheeled, semienclosed jeep ambulance proposed by General Shambora from Army Field Forces during World War II would have been the answer, but it was not accepted. The new 100-inch wheelbase, ½-ton vehicle may be the answer, but I have seen little come of it yet.

The ¼-ton litter-jeep ambulance has few flat limitations, but a number of relative drawbacks. It is awkward and uneconomical. In cover and comfort to the patient it is no better than a litter haul, but it moves somewhat faster and is much easier on the litter bearers.

The new ¾-ton ambulance (M37) is, on the whole, a good vehicle. It is heated and lighted and has space for an attendant to work. It takes a little finagling to load into it patients with large splints, but otherwise it has almost no limitations, from a professional standpoint, for use in the forward areas.

The indications for helicopter evacuation expand in direct proportion to the availability of the machine. I doubt if we should ever consider using it for routine evacuation; that would be a luxury we can ill afford. Here is my listing of indications, in order of priority:

1. True surgical hospital cases: wounds of the belly, chest and head; and any case with uncontrollable hemorrhage or unresponding shock.
2. Other serious cases, when the time, distance and other circumstances of available surface evacuation indicate significant detriment to the patient: fractures, major extremity wounds,

heavily sedated or comatose patients, hemorrhagic fever, major burns.

3. Other patients, on the basis of comfort and convenience of the aerial means, for example: mumps, moderate burns, major contusions and sprains, less severe wounds.
4. Routine: consultations, laboratory referrals, colds, minor wounds.

We had, in Korea, sufficient lift for the worst of the priority 1 group, except during a few periods of unusual activity. This lift could not be portioned out with 100 percent efficiency, and sometimes the machines were down for maintenance, or off on less important missions, or the night was too dark to fly. Roughly speaking, something less than half of the true surgical hospital group was moved by helicopter.

No formal establishment of priorities was necessary. When casualty flow was heavy the unit surgeons selected the worst cases. When casualty flow was light, unit surgeons made almost as many requests for helicopter missions, but were far more liberal in selection, and many of the second priority group could then be taken care of. A tenfold difference in casualties between two successive months would be marked by only a 20 percent difference in missions flown.

Hemorrhagic fever patients, or reasonable suspects, were arbitrarily accorded first priority, and many of us felt that the rapid and smooth evacuation to a conscientious nursing staff contributed as much to the lower mortality as did the complex and intensive treatment after admission. I have, however, listed these patients in the second bracket, so that priority 1 will serve also as the criteria of selection for evacuation from the battalion aid station to the surgical hospital. Generally speaking, with the helicopter lift that we had in Korea, any evacuation by helicopter from the battalion aid station habitually meant an admission to the supporting hospital, with the exception of the hemorrhagic fever patients who were flown all the way back to the hemorrhagic fever center, or transferred (near the surgical hospital) to light fixed-wing aircraft for the longer rear lap. When a decrease in casualties made possible a broadening in selection of patients for helicopter evacuation, the surgical hospitals took a wider variety of patients. Thus in a quiet period a casualty with a bullet wound through the thigh was flown to the surgical hospital and operated on there. When things started popping, he went by ambulance and rail and was operated on in Seoul, or even Pusan.

The group of patients who are *not* first priority surgical cases are right now of greater interest to me than those who are. They have not been so much publicized, their plight is not dramatic, success or failure of treatment is not as clearly portrayed as is an unequivocal change in mortality statistics. They rarely die from direct results of their

wounds. But they are far greater in number. They take a greater sum total of time and effort in treatment in a theater of operations and they offer more prospect of salvage for further military service.

This is perhaps the time to bring in my own classification of wounds by relative severity. It has no recognized standing; the adjectives cannot be held officially equivalent to any accepted military term; but it is very handy for rhetorical purposes.

The "band-aid" wound is *trivial* or insignificant, if the physical and psychological makeup of the soldier is such that he dismisses it after a wipe with a dirty handkerchief. It is *minimal* if the soldier insists on bringing it in to the medical officer, for an official tag to make him eligible for the Purple Heart.

The slight wound that requires only débridement and delayed closure is *minor* if it can be treated at the division clearing station. The soldier definitely has been wounded. He can be treated and returned to duty by the medical service of the combat division.

The soldier with the *moderate* wound cannot be restored to duty from the division clearing station because of the time required for healing and convalescence, but the wound may be appropriately subject to débridement at the division clearing station with the patient being immediately moved to a rear hospital for further treatment, or the casualty with the moderate wound may be moved through the division clearing station to the evacuation hospital for operation there.

The *major* wound is the typical evacuation hospital case: second priority for helicopter evacuation beyond the surgical means of the clearing station but not demanding immediate lifesaving surgery.

The *critical* wound is the so-called "nontransportable" of World War II, the typical surgical hospital case, first priority for helicopter evacuation.

The Role of the Clearing Station

The function of the clearing station in the surgical treatment of the minor, and certain of the moderate, wounds was somehow quietly forgotten between the end of World War II and the middle of the Korean war. It came as a shock to the Surgeon of Eighth Army and his staff that the clearing stations supporting the several sharp actions in the fall of 1952 had degenerated into simple relay posts, where patients were logged out of the division, and transferred to ambulances of the field army medical service. Part of this was certainly due to the fact that the shortage of medical officers forced us to operate clearing stations with 4 or 5, or even 3 officers, compared to 11 provided by the Tables of Organization. That this was not the whole answer is proved by what the clearing stations were able to do with a limited staff later in 1952 and in 1953.

The doctors were unhappy, and justifiably so; their professional tasks were frankly menial. A tremendous technical and professional personnel potential was going to waste, as were expensive equipment and facilities comparable to those of a well-run hospital emergency ward: oxygen, suction, blood, refrigeration, laboratory, good lights, basic surgical instruments, and a $2,000 operating table—three complete sets of equipment, one in each platoon of the company. But the worst of it was the tremendous burden of minor and moderate wounds that were thrown on the evacuation hospitals. Even with a normal allocation of evacuation hospitals this is not the best handling of such cases, and with the extreme scarcity of evacuation hospital beds in Eighth Army the implications were serious. In an evacuation hospital admitting ward a man with a minor wound finds himself repeatedly and properly, but almost indefinitely, put back at the foot of the list because of higher precedence accorded the more serious casualties who continue to come in. At the clearing station he is, by virtue of the lesser severity of his wound, at the top of the list for operative treatment. After débridement he can wait out evacuation, transfer and admission at various stages without harm.

Rather surprisingly, we ran into a certain amount of resistance or, shall we say, reservation of approval, from consultants at higher levels, when the campaign for resurgence of the surgical function of the clearing station was opened. The objections were on clinical professional grounds; the operational advantages were accepted. The main objection is evident: The clinical determination of a wound as "minor" can never be absolutely certain, since even the most insignificant appearing puncture of the thigh may involve the abdomen, or a trivial laceration of the shoulder may involve the chest. This criticism is not wholly valid. We must not discredit clinical judgment in favor of wholesale x-ray and laboratory examinations. And, at the battalion aid station or clearing station, when the *clinical* diagnosis is that the wound of the thigh does not involve the belly, the patient automatically is placed in a low priority and evacuated by surface transportation to an evacuation hospital. If the initial clinical diagnosis is wrong, the proper diagnosis will then be made only after the long delay of evacuation or after development of significant peritoneal symptoms en route. Surely this is not preferable to making the diagnosis at the clearing station by débridement and surgical exploration of the wound track.

The system received enthusiastic approval and support by the Surgical Consultant to the Eighth Army Surgeon, whose criteria for operation at the division clearing station have been published (*2*). Wounds

involving the cranial, pleural, and peritoneal cavities, and wounds with fractures of long bones or associated vascular or peripheral nerve injury were excluded.

The need for equipment and personnel to administer general anesthesia was expressed by several divisions. On this subject there are mixed feelings. In one instance we furnished apparatus to a division which had a qualified medical officer anesthetist assigned, and it was profitably used. As a policy I am against it. In practically all cases that meet the spirit of the criteria for operation at the clearing station it can be done under local anesthesia.

X-ray equipment is another question. It is not particularly dangerous to use; at least mistakes are not so likely to be fatal in radiology as in anesthesiology. I fail to see that it is essential for the performance of minor surgery of high professional quality, or for the selection of patients for operation. But I feel that it might be justified, on the basis of reduction of manpower loss from disease and nonbattle injury, provided the situation were quiet, or the requirements for additional personnel, transportation and electric power in the division medical battalion were clearly met. The Table of Equipment of the clearing company may be the place to use up (on the basis of one per company, not one per platoon) the recently developed 15 ma. units which most of our hospitals ignored as useless and wanted no part of.

To summarize the role of the clearing station, and the professional considerations in its operation:

Functions:

1. To serve as an infirmary for minor medical illnesses, and an emergency ward for wounded.
2. To treat and return to duty appropriate patients.
3. To log out from division records those casualties requiring treatment by other installations, for whom replacement will be required.
4. To offer small-scale "medical center" services for the practitioners in forward units: laboratory, pharmacy and consultation.

Professional considerations in evacuation *from* the clearing station are:

1. Is further evacuation necessary; or can the patient be treated, held and returned to duty without losing him from the division?
2. Is immediate major surgery necessary? If so, the patient will be transferred to the adjacent surgical hospital, which is also receiving patients by helicopter direct from the battalion aid station.

3. If the wound does not require immediate major surgery, is it properly operable at the clearing station? The patient will in either event be transferred to a rear hospital—after, or for the purpose of, surgery.

The Mission of the Surgical Hospital

A great deal has been said, written and discussed about what the surgical hospital is supposed to do, and how. Some of the presentations are hasty or prejudiced; a few are contradictory; many are controversial. In spite of the fact that the basic Table of Organization and Equipment was evolved only in 1945, and the only actual experience with the organization was obtained in Korea, which I have already cautioned is a limited experience, I feet that the mission of the unit is perfectly clear. It is the mission officially proclaimed in the Training Circular, Field Manuals, and Table of Organization and Equipment: to provide a mobile surgical facility for the treatment of seriously wounded casualties within the division area.

You are all familiar with comparable units used in World War II: the Portable Surgical Hospital in the Pacific, and the Field Hospital platoon (reinforced with surgical teams) as originated in the Mediterranean and later successfully used in Europe. These two organizations met the pressing need for major surgical facilities located well forward. When the front is moving, "well forward," of course, means truly mobile. Our former surgical hospital, which many of you may not remember, was a 400-bed unit, well equipped, but unwieldy.

In the early days of the Korean war the surgical hospitals were expanded into 200-bed units comparable to half-scale evacuation hospitals. They were located well behind the division cleaning stations, on the line of communications between the divisions and the so-called evacuation hospitals, which then in reality represented a combination between station hospitals and communications zone general hospitals. The 200-bed unit received any and all patients from the divisions, thus contributing indirectly to the deterioration of the clearing stations.

The initial reasons for using the surgical hospitals in this manner did not long persist. It was found feasible and quite desirable to locate the surgical hospitals well forward and to institute an effective selection system in the clearing stations. Although it was not until February 1953 that the 200-bed Table of Distribution surgical hospitals officially returned to 60-bed Table of Organization status, they functioned as the latter throughout 1952. They were not, however, located always directly adjacent to division clearing stations. Divisions on line were rotated frequently, and a United States division was often replaced by a division of the Republic of Korea Army. In view of the well-developed communications we had at the time,

and in deference to the convenience of the units and the heavy investment they had in comfort and luxury construction, they were left slightly to the rear of divisions, in central locations from which they could normally support any division sector within the corps. It was not that they *could* not operate forward, or could not keep up with a moving division. Each of them proved, in realistic training exercises (in which the Communists happened to cooperate unknowingly by throwing local attacks and producing casualties), that they could leave behind their buildings and walkways and clubs and fancy quarters, load up the tentage, and go. They did beautifully. They proved the adequacy of the current personnel structure, equipment list and training doctrine.

Table of Organization and Equipment 8–571A (15 October 1952) is instrinsically adequate. It can and will be developed and improved upon, but right now it provides for an organization that can turn out professional work of a consistently superior quality.

The hospital needs a 5 to 10 percent increase in enlisted personnel, in the administrative and specialist fields, and a redistribution of duties among the personnel now on the Table of Organization. It needs a moderate increase in electric power, and a definite increase in tentage. About one-third of the tentage needed to set up a perfectly orthodox installation is not authorized by the Table of Equipment, which provides nothing except pup tents for personnel quarters, and no shelter for the mess except a kitchen fly. But any proposed change must be exhaustively considered on both clinical and operational professional grounds. The restrictions on personnel available to us in Korea, and likely to be available to us in the future, are painfully tight, and almost harshly inflexible. In ultimate principle the decision we may have to make with reference to a major addition will seem crudely blunt: Will the sum of our military patients benefit more from a smaller number of units that are a little better, or from wide distribution and close support by the same or greater number of units that meet the then current standards of best professional practice?

The surgical hospital is designed, equipped and staffed to perform—with the highest professional standards—formidable initial surgery of all types. Its special characteristic in this respect, distinguishing it from evacuation hospitals, general hospitals and large station hospitals which can, technically, perform the same operative procedures, is that it is small enough, light enough and flexible enough to offer this surgery in a physical location which assures a reasonable minimum time distance from point of wounding to the operating table. Being small, its facilities should appropriately be reserved for the treatment of those patients for whom time lag is of pressing importance. I

offer the following as a loose list of wounds in order of anatomical and physiological priority for admission to the surgical hospital:

Uncontrollable hemorrhage or shock
Belly
Throat
Head
Chest
Extremities: gross wounds, or those with known or suspected major vascular damage.

A detailed discussion of the treatment accorded these wounded is beyond the scope of my presentation.

The professional considerations in arranging evacuation after treatment—selection of the time, the means, and the channel or destination—are relative, depending on just how fast business is at the moment and is expected to be in the near future. I might illustrate this by presenting several of the criteria that were utilized at various times for deciding the time of evacuation of patients with one particular type of wound—perforation of the large bowel. When things were unusually quiet in early 1952, our surgeons had time on their hands and hospitals had beds to spare. Some of the men were then repairing the bowel and exteriorizing it for observation, or even making primary repair and closing the abdomen, depending on private nursing and close surgical postoperative care to insure a successful result. I mention these choices to denounce them as inappropriate for general use in forward area military surgery, but a third method illustrates the detailed and extensive treatment that we could give during a slack period. In some cases a proper colostomy was performed, and the patient held at the surgical hospital for final healing, and re-anastomosis of the bowel before he was evacuated further.

When things are not quite *that* quiet, the patient was held until the colostomy was functioning well and he could help take care of it during evacuation.

When the front was not calm, but tactical action was still sporadic, the patient might be held until the incision was clean and healing. When things were busier, he might be moved as soon as bowel sounds were restored. When the situation was really busy he might have to be moved the day following operation, and when the situation was frantic he might have to move out as soon as he recovered from anesthesia, to make room for someone in a more desperate situation.

The minimum requirement for evacuation of a patient with a *neck* or *deep face* wound is the cessation of bleeding, and adequate airway and unequivocal recovery from post-anesthetic nausea. In spite of the discomfort, an ambulance is preferable to a helicopter, until such time

as we get an adequate helicopter ambulance with room for an attendant to work. Our present ¾-ton ambulance makes good provision for nursing care en route, in fact, far beyond the technical capacity of our ambulance drivers, who are usually medics in a very limited sense. For special cases, a qualified technician from the hospital can go along for the next lap.

For *head* cases I must give an equivocal answer. I am still told by some that these patients travel better preoperatively than postoperatively, but I am not wholly convinced. The urgency of an untreated head wound is an overpowering stimulus to assume a manifest risk of transportation. If they die en route, we have done our best and death is held to be prima facie indication that they were unsalvageable. Once they have reached the care of the neurosurgeon, he is understandably loath to release them until he can confidently predict a safe journey. Like most general surgeons I will dodge neurosurgery and request to be relieved of the decision, but if I must state the criteria, as far as I am concerned the head wound patient can be moved as soon as the surgery is over, the patient is in proper position or on the proper apparatus, and his blood pressure is stable. These patients do require competent technical attendance en route. Their relatively small number, their serious condition and their need for close attention warrant the making of special evacuation arrangements. In Korea they were periodically collected by special helicopter lift (preferably by the larger H–19, with room for an attendant) and flown to rear airfields to meet pre-scheduled aircraft for immediate evacuation to Japan. They ordinarily did not pass through evacuation hospitals or intermediate holding facilities.

As for *chest* wounds, I feel that there is little excuse for evacuating any man from a surgical hospital with a functionally open wound of the chest. Some sort of surgical or dressing closure can be effected. In spite of their inherent appeal, I take a dim view of all sorts of tubes, flutter valves, indwelling needles, or drainage systems. The chest patient should not be evacuated until he is sufficiently stabilized that he can be cared for by intermittent thoracentesis, at intervals that can reasonably be met during the evacuation as planned.

The patient with an extremity wound and *vascular* injury should, ideally, be evacuated only after the initial reaction of the tissues to trauma is subsiding and the probable outcome from a circulatory standpoint is no longer in doubt. If the adequacy is evident, the consideration is one of mechanical stability of the repair during movement by the means contemplated. If adequacy is yet in doubt, the patient should be held so that he may have the benefit of all available measures to tide the limb over. If the circulation is patently inadequate, the extremity should be dressed to protect it from further

trauma, but it may as well demarcate during evacuation as in a hospital.

The patient with a *grossly damaged extremity* does not travel well. A truly mobile rig for an amputation stump is very difficult to fabricate. If the volume of casualties does not preclude it, no patient should travel in a cast that is less than a day old: that day, of course, includes some close observation. No patient should ever leave the surgical hospital in a cast unless the cast is split.

The choice of mechanical means of transportation is based more on the severity of the wound (or rather, the general condition of the patient) than on the anatomical location or type of wound. The ambulance train offers the best facilities for care en route, and gives the smoothest ride; these advantages are balanced against the longer time. The cargo aircraft is second best, except that the shorter time in transit is a partial compensation. The large H–19 helicopter and the ¾-ton ambulance are comparable to each other in facilities for patient care, though vastly different in speed, comfort and cost. In respect to care en route the small H–13 helicopter does not even come up to the standards of the litter jeep, but its versatility and speed make it an exceedingly valuable machine. Having weighed these various considerations in selection of the means we then come up against the one that is overriding: which one is available at the time?

The traditional means of evacuation from the division clearing station or surgical hospital to the evacuation hospital is by ambulances from separate ambulance companies of the field army medical service. This held true in Korea, but only for the initial stage of the trip to the rear. Patients were transferred from ambulances at the earliest possible point, to make the greater portion of the rearward journey by air or rail. This transfer was indicated on two considerations: the health and comfort of the patient, and the pressing need to conserve our limited ambulance lift.

Patient Holding Operations

At each point of transfer—the railhead or airhead—a facility for the temporary holding of patients is *mandatory*. At airheads the requirement is based in part on the irregular and unpredictable nature of air transportation. At railheads this factor is less prominent, but then there is the additional requirement for holding patients during the period of buildup of the trainload before the scheduled loading time, even if the rail system is considered absolutely dependable. Our holding facilities in Korea were kept adequate in number and distribution, even when this meant subordinating or shortening other medical support operations.

The holding unit has never been regarded as glamorous, and there is a tendency to forget the importance of its position in the provision of uninterrupted medical care of the wounded. The stress of an ambulance ride of 1 to 3 hours, from the surgical hospital to a tent on an airstrip or a rail siding, is not insignificant. Added to this is the period of waiting on an average several hours more; sometimes as short as a few minutes, and occasionally longer than a day. The holding station is no place for any patient who is still in the process of resuscitation, but it accumulates patients of all grades of helplessness, with wounds of all locations and all degrees of severity, and in various stages of treatment. These add up to a requirement for a professional operation of some extent.

Our holding units in Korea were adequate in capacity, physical facilities and equipment, but I was never particularly proud of the caliber of their professional work. The screening and rescreening of patients, interim medical care and nursing—even in the simple arts of bedding down and feeding the litter patients—left a great deal to be desired. There is nothing wrong with the "system" that requires that this be so. On-the-job training, repeated indoctrination of personnel, and continued interest and supervision by nursing and surgical consultants will take care of it in time.

Allocation and Use of Evacuation Facilities in Korea

Our allocation of ambulance companies in Korea was about half what was required. I make this blunt statement with confidence that I can support it both on theoretical and practical grounds. I will mention it further in my later discussion on Evacuation and Specialty Centers. But you may ask now: How can it be said that we had only half enough when we obviously did well enough with what we had? We were able to operate an admirable evacuation service only as a result of the following special blessings:

1. The availability of common carrier (rail and air) transportation in the forward position of the combat zone.
2. The low average casualty incidence during most of the war.
3. The courtesy of the Communist air force, and our faith in the ability of the United States Air Force to maintain air superiority.

In the eastern half of the front, evacuation was principally by air. The forward rail network was wholly lacking. A single-track line ran up from the south to a point just over the combat zone boundary and angled over to connect with the main western line at Seoul. In the forward portion of the combat zone there were four major valleys or plains, each with an airfield located not more than 1½ to 2 hours away from the usual location of division clearing stations and surgical

hospitals during the latter half of the war. Holding units at the airfields assembled the loads of patients of all types (toothaches, backaches and consultations included), logged them in and out, and prepared the flight manifest before the aircraft arrived. And, of course, they held and cared for the patients during the process. The typical length of stay for patients was 3 or 4 hours, sometimes overnight for those with minor injuries evacuated direct from division clearing stations, sometimes only a few minutes for seriously wounded patients handled specially on an "appointment" basis. These figures apply, of course, only if the airplane flies as scheduled. I bitterly recall one month in which weather closed a key field for 13 days, 10 of them in distressing direct succession. At such times we necessarily used ambulance transportation, at a minimum of 11 hours per round trip. Under those circumstances we simply could not have supported a division attack against determined resistance, without evacuating the less seriously wounded on ammunition and supply trucks returning to the rear over the same long haul. In general, we could not have operated an efficient medical evacuation system in the eastern sector without the help of the Air Force. We are deeply grateful for the favor. It is *not* a statutory function of the Air Force to provide air evacuation *within* the field army area, but only *from* the combat zone to the communications zone. This is an assigned function of Army aviation, but diversion of all of the aviation in Eighth Army to purely medical missions could not have done the job, nor will Army aviation ever be able to do it with aircraft of the present type. With the exception of the H–19 helicopter, no Army aircraft in current use is an adequate patient-carrying vehicle. And the H–19 is far too expensive and complex a vehicle to use for routine hauling.

It may be heresy to suggest it, but Army aviation, or more specifically Army Medical Service aviation, should include aircraft comparable in capacity to the workhorse C–47: say, light assault transports of the C–122 type. Such a vehicle could be profitably used in the lateral and rearward movement of patients entirely within the army area, and there is no more basis in statute or logic that it be operated by the Air Force than that the Navy take over from Army engineers the operation of river-crossing rafts. A flight of six C–122's could have been economically employed by Eighth Army even during its quietest periods, and a squadron of 18 would have been barely sufficient during the most active times.

My only criticism of air evacuation in Korea was in the mechanism of control. Once the aircraft was allocated and scheduled, the service by the air crews and medical crews was superb. But getting the aircraft was a constant struggle, at least during the latter half of the war. We had to call Japan, a day in advance, for every aircraft that we

used, even though it was used only between two of our own units in Eighth Army. We were required to substantiate our request with the actual numbers of litter patients and ambulatory patients to be moved. We naturally took to the crystal ball method of making such computations, since many of our patients to be lifted tomorrow have not yet been shot today. When our forecasts were badly off, or even initially when we made any unusual or ostensibly odd request for air lift, we were criticized by the people in the Air Force medical evacuation unit and called upon for an explanation. I have spent hours of valuable time, and many dollars of the taxpayers' money, for long calls over Japanese toll lines trying to make, without breaching security, an explanation which, I sincerely believe, is of no legitimate concern to the Air Force except as a matter of historical information. If air evacuation is going to be useful and dependable, our allocation of lift capacity should be definite, and the answer at the other end of the telephone should be positive: "Yes, we can do it," or "No, we cannot do it" (the lift is technically not feasible, or aircraft are not available), or "We can do only so much of it, or we can do it at another time," never a negative and indecisive "*Why* do you want it done?"

We did not have the same problem with rail evacuation, which supported our medical units on the western half of the front. The hospital ward cars and the medical crews belonged to a unit of the Army Medical Service; the railroading was in the hands of units of the Transportation Corps. Both these units functioned under the communications zone organization which supported Eighth Army, but with respect to the service they rendered and the channels of request and control, they might as well have been integral elements of the office of the Army Surgeon.

The usage of rail evacuation in Korea was prominent at all stages of the war. In the Pusan perimeter the rail system was well developed. In the fluid phases there were many examples of effective utilization of various short stretches of track and all sorts of odd rolling stock. During the latter half of the war there were two preeminent features: first, the extensive use of rail transportation—there was even a baggage express system up to several of the division areas, and we belatedly started moving some of our blood shipments by rail—and second, the proximity of rail operations to the frontline. Some of the major and long-used railheads were within range of enemy light and medium artillery (the enemy proved that for us), but even so there were raised eyebrows in the Army staff when the medics established a holding facility at a lonesome terminus only 9,000 meters from the frontline. This installation was frankly invaluable in support of the Triangle Hill and Whitehorse Mountain operations.

Except in periods of consistently active battle it was unnecessary to run ambulance trains more often than once daily; the two to four divisions supported by that rail line generated a one-train patient load each day. The hub of our rail operations was Seoul. There the seriously wounded patients were off-loaded for air transportation to Japan. Less seriously wounded men—those who could be expected to recover within the time period of the current evacuation policy—went on down the line to hospitals in the communications zone.

Except for such patients as were flown by helicopter direct to hospital ships in the harbor at Inchon, the 1st Marine Division was supported by rail, from Munsan, through Seoul to Inchon. With the extreme tides that occur at Inchon it was necessary to schedule the trains for the port siding at the time of a high or rising tide. Since hospital ship patients who were evacuated from the ship to Japan also came in by rail from Inchon to the airfield, this was an operation that epitomized tri-service cooperation.

The function of the hospital ship in Korea is indicated by the fact that it retains that title yet, while the late "hospital" train is now more aptly called an "ambulance" train. The hospital ship was utilized as a floating hospital, primarily as an evacuation hospital for the 1st Marine Division. Its role in the transportation of patients was only incidental. As ships were replaced and moved back to their base in Japan they might carry along a few special patients; the bulk of their load was transferred to the new ship arriving on station.

Evacuation to Japan was almost entirely by air, using the larger aircraft; normally the four-engine C–54's (later replaced by the C–124's), occasionally two-engine C–46's. The aircraft were obtained through the same channels used in arranging intra-Korea evacuation. Requests were made to the Air Force medical evacuation squadron in Japan. These requests were initiated by Eighth Army. Theater headquarters maintained the medical regulating function by controlling the hospital of destination in Japan.

This link in evacuation worked well. It is an entirely normal function of the Air Force. Aircraft were usually available in adequate quantity and there was less bickering involved. The extreme fluctuations in our requirements naturally inconvenienced Air Force and theater planning. This fluctuation was due to two factors: our inability in Korea to shift patients laterally to the full extent desired, and the lack of any significant cushion of beds to absorb sharp increases in casualty load.

The Utilization of Evacuation Hospitals

The lateral redistribution of patients is a process of far greater importance than is indicated by the little attention it has received.

The essential time consideration in the initial evacuation of a wounded man is not how soon we can get him to a hospital, but how long it will take to get him on the operating table. The nearest hospital becomes swamped first. The surgical backlog, expressed in hours of surgical lag from time of admission to time of operation, becomes so high that even with conscientious application of clinical priorities a critically wounded soldier will be much better off by going a longer distance to a hospital that is ready to treat him immediately. This principle was practiced in World War II, in the control by the Army Surgeons of the distribution of patients by ambulance from divisions to the several supporting evacuation hospitals to the rear. The development of the helicopter and intra-Army air evacuation made possible the shifting of seriously wounded patients laterally (or even forward) between the surgical hospitals located across the front.

In one of the actions on "Porkchop" the casualties quickly tied up the surgical hospital in direct support, overflowed to the nearby Norwegian Surgical Hospital and loaded the facilities of the nearest neurosurgical detachment. The next patients with head wounds were then flown by Army helicopter to the hospital ship at Inchon. The less seriously wounded were culled out and moved to the evacuation hospital near Seoul and the seriously wounded were spread out to other surgical hospitals across the front. Finally it was necessary to move several aircraft loads of those with minor wounds entirely across the front to the eastern evacuation hospital, which was, at the time the action broke, out in the field in tents on a training problem, conveniently located right on an airstrip. Thus this single action, occurring entirely in the sector of one regiment of one United States division, filled every operating table in Korea except those in the one surgical hospital on the far right.

The impact of the seriously wounded on the surgical hospitals in this instance was less disrupting than the avalanche of lesser wounded on the evacuation hospitals. To make room for them it was necessary to dump wholesale loads of common colds, consultations, and other trivia on the hospitals in the communications zone, or in Japan, and even so the surgical lag at the evacuation hospital for operation on some minor wounds rose to 30 to 36 hours, even after the long period of delay in evacuation from the front.

This is what I mean by saying that we operated on a shoestring in Korea. Without dependable rail transportation and freedom of the air, a sustained casualty flow of major degree could not have been accommodated by the medical support we had in Korea except with periods of stagnation and significant lowering of fundamental professional standards.

By the summer of 1952, successive reductions in the troop ceiling on medical units in Eighth Army and the Far East Command, and the dwindling of the replacement stream to the point that we could not staff the units we had, brought Eighth Army down to two functioning evacuation hospitals. One was in the east, and the other in the west, and they hardly could have given effective mutual support in the event of movement forward or rear. They were kept busy most of the time with station-hospital-type patients—disease and nonbattle injury. Even with expansion of number of beds their ability to absorb a sudden increase in admissions was limited to one full trainload of patients, or eight C–46 aircraft loads. By the time the second lift came in, arrangements had to be completed for the simultaneous transfer of patients to Japan or the communications zone before the second group could be cared for.

Allocation of Medical Manpower Resources

These arrangements *were* made and *were* executed. The hospitals in Japan supported the combat operations as if they were in Korea and wearing the patch of Eighth Army. The medical service in the Far East did not just "get by"—it turned out superior work. The medical service was *not* unduly imposed upon by these successive reductions in troop strength—the whole of Eighth Army was cut, and the whole war in Korea was fought on a shoestring by all the combat arms and supporting services. The Far East Command as a whole was spread extremely thin for its mission. But still all up the line, our troops are spread to meet the cold war over the whole world.

I wish to give no implication of complaint, but of caution. Do not accept the troop basis in Korea as an optimum for planning. Do not accept it as even an adequate minimum for Korea. The medical service in Korea functioned as well as it did by virtue of special circumstances that are not dependable assets to draw on in the future.

In particular I warn you not to accept the physician: troop ratio of 1950–53 as an acceptable standard. We did all right on 3.9 or so per thousand, worldwide, with most of the troops in the Army, Navy and Air Force on nonfighting fronts, and those in Korea favored by the special circumstances I have mentioned. If we had met with reverses or sustained heavy action, and if the medical service had stagnated as it might have, I am sure that medical manpower resources would have been released to the Armed Forces on a more liberal basis. I am alarmed to see a figure of 3.5 per thousand bandied about with the implication that it is to set the standard for any future war, not just the period of uneasy peace. And I am amazed that outside agencies take pride in having been instrumental in establishing such

an arbitrary and restrictive allocation of medical manpower resources for national defense.

I am confused by the continuous harping on the desirability for further curtailment of assignment of Medical Corps officers to nonprofessional duties. In World War I there were approximately 6.5 physicians, and 0.5 administrative officer per 1,000 troops. Now the total of 7 per thousand is split differently: approximately 3.5 Medical Corps officers and 3.5 Medical Service Corps officers. A good part of the increase in Medical Service Corps positions is legitimately due to increasing complexity of administration and operating of ancillary services. But not in the last decade do I recall a single instance in which the reduction in proportion of Medical Corps officers was accomplished by *replacement* in our manning tables by officers of the Medical Service Corps.

We have cut Medical Corps positions too far, and I flatly do not believe a ratio of 3.5 doctors per thousand is right. We have, in too many instances, compounded and confused the administration by adding personnel who are not really needed. I fail to see why a lieutenant is needed in addition to a sergeant to command a section (not a platoon, just a section) of nine litter jeep ambulances, or a section of six litter squads. I cannot conceive of a reason why a regimental medical company requires both a captain, administrative officer, and a lieutenant, mess, supply and motor officer. Nor can I imagine what keeps the administrative officer who is assistant platoon leader in the clearing platoon profitably occupied. Eighth Army officially and voluntarily offered, through both command channels and technical channels, to give up nearly 200 officer spaces for Medical Service Corps officers in tactical units, and this without hope or intent of increasing the number of our scarce Medical Corps officers. In other words, that portion of the 3.5 MSC's per thousand troops that these officer positions represented was in no way contributing to the reduction of MC's to 3.5. They represent in my opinion nonessential padding, and poor contributions to the prestige and importance of the Medical Service Corps. The future of that Corps appears to me to lie in its quality, not in its numbers. It is of interest to note that we did not propose reductions of MSC personnel in hospital units, nor did we propose to cut out a single position in grade higher than lieutenant.

The often repeated cry against placing medical officers in "administrative" or "nonprofessional" positions is not well titled. I would prefer to call it a cry against "non*clinical*" positions, except that it would then include objections against officers in laboratory research, which is nonclinical endeavor, but certainly not one we want to reduce. There is utterly no doubt in my mind that my own last four duty

assignments were intensely professional: commander of the medical battalion of a division; airborne division surgeon; operations officer for a field army surgeon and commander of a medical group. Yet all of these are positions which have been neglected in assignments; have been filled on occasions by Medical Service Corps officers by default; and have been held, by some, in private conversations, as coming within the group of administrative assignments from which medical officers should be relieved. This is a farce, but a strangely popular one.

Summary

I would like to summarize my discussion of professional considerations in evacuation with a listing of some essential features of a modern field medical service, with comments as to where and why we succeeded, and where, what and how we might have done better:

Exceptional in Korea		*Greater emphasis in future*
	Battlefield recovery, and treatment within the division.	X
X	Evacuation of forward units by helicopter.	
X	Close support of divisions by surgical hospitals.	X
	Evacuation hospitals to absorb the bulk of casualties.	X
	Specialty centers for utilization of scarce personnel.	
	Adequate surface transport for evacuation.	X
X	Aerial evacuation within and from combat zone.	X
	Preventive medicine service.	
X	Organized current research program in combat zone.	
	Quality of professional care throughout.	

My listing of check marks in the "exceptional" column is an evidence of prominence, not quality.

Division medical service in Korea was good, but most of those connected with it will agree with me that it needs more medical officers than we could supply from our resources in Korea and the Far East, and it needs more interest in the matter of selection, training and assignment of officer and enlisted personnel. It deserves a great deal more attention from the research people. And it stands to profit us more by such research than does any other field.

The value of *helicopter evacuation* from aid stations is apparent and has been widely discussed. The first trial in Korea was a great blaze of glory. The machine is here to stay; the program will coast into the future of its own momentum. If anything, we need to see that the machine is not oversold, and that sober attention is given to the relative cost of the use of such an expensive means, the propriety of using commissioned officers as ambulance drivers, and the development of a vehicle which is technically adequate for the transportation of patients. Let me lay one ghost here: the helicopter is not vulnerable to enemy air, at least no more so than the jeep or truck.

Korea was the first trial of the *surgical hospital*, and its debut was also brilliant. We do need further emphasis on the development and use of this unit, particularly its role in close physical support of the division. This function will never rightly be lost to rear hospitals by virtue of swifter and more capacious and more flexible air transport—at least not while the infantry moves on the ground and is supported in most part by surface transportation.

The utilization of *evacuation hospitals* in Korea was prominent in a negative sense, as pertains to service to battle casualties, and in a positive sense only with respect to the great amount of work that was done for the nonbattle sick and injured. This applies, of course, to evacuation hospitals generally. As individuals, the two we had assumed a tremendous load as a result of the missing ones that we needed, and they did yeoman work. The shortage of evacuation hospitals and the resulting inability to absorb sudden heavy casualty loads was the *most disturbing single deficiency in the organization of the medical service in Korea.*

Although the military surgeon must be a true general surgeon, prepared to operate on anything between the scalp and the toenails, expert service must be provided in certain of the *professional specialties.* We cannot hope to do this by apportioning the specialists so that each medical unit has its across-the-board share. Some of the units will wind up with half a neurosurgeon. The specialist with limited training in his field works better with and under guidance of his colleagues, and the answer is the concentration of certain specialists at designated centers. This will be the subject of a separate presentation.

It may seem prosaic to you, but I wish to stress again the need for *adequate surface transport* for evacuation. So long as most of the fighting men are on the ground, and most of the tonnage of food and gasoline and ammunition to support them comes by pipeline, road and rail, we must have an adequate surface evacuation system. The helicopter can, technically, eventually replace any of our standard cargo or evacuation vehicles. And it will—for certain units, certain special functions and certain tactical operations. Fixed-wing aircraft and the convertiplanes that will come during our term of service cannot replace any significant numbers or types of standard surface vehicles. They supplement and complement, and contribute to flexibility. They will save lives, but not units and personnel spaces.

The prominence of the use of *rail transportation and evacuation* in Korea is a feature that is not likely to disappear in the future. A rail system and a determined field army engineer make a combination that is far less susceptible to destruction by enemy action, by either conventional or atomic weapons, than the public has been led to be-

lieve. The trains ran in North Korea, they ran in Germany in World War II, and they ran into Hiroshima almost immediately after the bomb. They may not have run on time, or smoothly, but they hauled tonnages that would require a staggering airlift to compete.

Air evacuation in Korea was outstanding. As I have said before, we could not have operated our medical service without air evacuation, within Eighth Army and to Japan, and without depending on the Air Force to fulfill its first duty of attaining and maintaining air superiority. For the future we need a great deal of attention to developing a type of aircraft for evacuation within the field army, and developing the organization and control of the system.

Preventive medicine service was in Korea, and will be in the future, accomplished in keeping with the finest and deepest traditions of the Army Medical Service.

Combat zone medical research in Korea was certainly exceptional. It will continue to be a prominent element in the future and will, I hope, push forward in the combat zone, even in face of the difficulties of mobile warfare. It will be altered slightly in orientation and methods, and it has reached such proportions in personnel, service support and scope to indicate the need for formal organization and control.

You will note that I have not starred the final consideration of *over-all professional quality*, either for Korea or for the future. Military medicine goes along with civilian medicine and leads it or follows it in all its aspects. The difference in our military practice between World War II and Korea reflects the startling advances in medicine of the past decade. The Army is as interested in the standards of medical education and medical practice as is any civilian agency. We draw our doctors from American medicine. From a healthy population we draw our soldiers and we are supported by a productive industry.

For this reason I am depressed to see statements made which indicate that the Military is in competition with civilian medicine, in particular the open implication that the requirements of the Military for medical manpower threaten the quality of medical care of our population as a whole. This is selfish foolishness. Medicine on the home front in World War II did not suffer in quality—only in sweat and inconvenience. And at that time there was a vastly greater proportion of American medicine in uniform.

I am certain that the Military deserves a more liberal access to and use of medical manpower than the starvation level we have worked under for the past few years. All of you who have had anything to do with assignment or management of personnel in Korea, in Japan or in the United States know full well that we led a hand-to-mouth

existence. Every transfer of a single individual overseas was followed by a fingernail-chewing suspense waiting for his replacement to return. Every loss of an individual from overseas—even on his return for emergency leave or board examination—was keenly felt, and required all sorts of shuffling of people to cover the vacancy. Divisions in the United States, supposedly training or ready for a combat role, existed on one or two medical officers per division, with noncommissioned officers or Medical Service Corps officers running sick call.

As is the quality of American medicine as a whole, so will be the quality of medicine in the Army. Although the process of evacuation of the wounded has little counterpart in civilian medicine, it is a truly professional endeavor—in its planning and management, and in balancing the administrative requirements and limitations against the probable professional outcome. We must get more Medical Corps officers out of wards and clinics and into field units. The quality of medical evacuation, including the medical care en route, will depend on the amount of *professional* interest and ability that goes into it.

This is the prime of the "Professional Considerations of Patient Evacuation."

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TRIAGE IN THE KOREAN CONFLICT*

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The experience on which my address is based is that of 19 months on the eastern front in Korea during 1951–53. This experience provided primarily an opportunity to study the casualties from the time of injury to the time of definitive surgical care and secondarily, an opportunity to study and to follow personally a few patients through the evacuation hospitals in Korea, the Army hospitals in Japan and on back to hospitals in America.

During most of 1952–53 the front lines were stable and the flow of casualties was generally small. One might think that triage was unnecessary, but triage was employed in the management of every casualty.

The term, *triage*, was derived from the French, *trier*, meaning to cull. It was the term used to designate the separation of the coffee beans from the refuse or in Biblical terms, to "separate the wheat from the chaff." Triage might, therefore, be defined as an evaluation and classification of casualties for the purpose of treatment and evacuation. It involves the evaluation of a single casualty or many casualties. It involves decisions as to emergency therapy, the lack of need of therapy, the hopelessness of therapy, and the priority of therapy and evacuation. What more important life-dependent decisions are ever to be made by a medical officer?

We speak of importance of triage. Importance to whom? To the wounded soldier, to the unwounded soldier, and to the American people. Here more than anywhere else in the field Medical Corps we must define our purpose, for decisions in triage may necessitate that even among those already wounded some must make additional sacrifices for the common good.

The purpose of the Medical Corps in support of a combat army is first to help win the war—to support the health and morale of the fighting troops. The second responsibility is to support the wounded casualty.

Included in triage, therefore, must be the separation of the wounded into two groups: first, those able to continue combat and, second, those requiring evacuation further to the rear. No definite criteria

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can be outlined by which this decision can be made as the criteria must vary in order to fulfill our primary purpose of supporting the combat troops. There have been times when any man able to fire a gun had to be returned to duty.

Triage involves primarily decisions regarding the urgency or permissive delay in providing supportive and definitive therapy. It therefore rests on our knowledge of the wound, of the patient's response to the wound, and the relationship of these antagonistic forces to the lapse of time. Such a concept might be summarized as follows:

1. The battle wound is dynamic. It results in a defect which produces a continuing, sometimes increasing, deleterious effect. The most urgent features of the wound are blood loss and mechanical defects. This continuing deleterious effect must be minimized by hemostasis, operative débridement and transfusion.
2. Following injury, the body responds to correct the defects. This is a continuing response of every organ and system which has been studied. This response may be lifesaving. Since this response involves the utilization of the body's reserve, the casualty, like the Army, has committed his reserves and is then quite sensitive and susceptible to further trauma or to the passage of time before relief.
3. Anesthesia or analgesics block part of the patient's response and, therefore, at least for the moment, may further the injury.

It is upon this background that triage should be based.

Let us re-examine the framework of triage in the Korean experience. Triage begins with the casualty himself. Will he continue fighting, summon aid, or walk to the aid station? Next the corpsman participates in triage. Will the casualty walk or be carried to shelter? Does he require immediate treatment for relief of pain or control of hemorrhage?

In Korea, triage centered to a great extent at the battalion aid station. Here the medical officer evaluated the injured soldier as to whether he should return to duty or be evacuated. He determined whether the man needed emergency care and whether he could be safely evacuated by ambulance or whether a helicopter should be called for rapid, smooth transportation to the surgical hospital. If the man was injured at night, should he be evacuated by ambulance or held until morning and moved by helicopter? In the standard chain of evacuation, the final decision that the injured man should leave the control of the infantry division and go to the surgical hospital was the responsibility of a field-grade officer at a clearing com-

pany. In Korea, the junior medical officer at the battalion level could, for practical purposes, make this decision by requesting direct helicopter evacuation of the more seriously wounded to the forward hospital, thus bypassing collecting and clearing stations. This privilege was not abused, but, to the contrary, resulted in the saving of many lives. Thus in Korea, when the casualty load was light, the battalion surgeon was the key man in triage.

It is at the battalion level, the combat level, that the vast majority of deaths occur. It is here, therefore, that we should center our attention in the future. Since most of the deaths occur prior to medical treatment, marked improvements may not result from extending our present therapy. Nevertheless, a determined effort to evaluate and solve the problems should be made by organizing a unit of mature surgeons to work as battalion surgeons. This is a real opportunity for the future which we cannot afford to overlook.

We were approaching the problems of triage and evacuation toward the end of the war by accompanying the injured from the combat area to the forward hospital and recording our observations during the various phases of movement and treatment.

The notes on such patients prove instructive:

While on patrol a 20-year-old private suffered a traumatic amputation of the foot and many soft tissue injuries when he stepped on a land mine. The accompanying medical corpsman controlled the hemorrhage with a tourniquet and returned the man to the aid station via litter. He was injured at 0200 hours and reached the aid station at 0500 hours. He was examined immediately. External hemorrhage had been adequately controlled. His blood pressure was 125/75, pulse rate 96, his skin slightly pale. Plasma expanders were available but the blood volume deficit did not appear dangerous. He was given penicillin and tetanus toxoid. His pain was not intense at the moment and morphine was avoided. He left the aid station via ambulance along with four other casualties at 0600 hours. At collecting station, 0630 hours, his blood pressure was found to be still approximately 125/75 but his pulse rate had risen to 110. There was little or no external bleeding. When he moved to a sitting position during examination, his pressure dropped to 80/40 and he became pale and nauseated. After he was again placed in supine position, his pressure gradually returned to the previous level. After a long, slow, bumpy trip to the clearing station, he arrived, at 0800 hours, with a blood pressure of 90/60, pulse rate 124. He was given 500 cc. of blood, which was often available there and his pressure returned to 120/75. Finally on admission to the surgical hospital, at 0930 hours, 7½ hours after injury, his pressure was 80/40, pulse rate 132. External bleeding was minimal.

Following subsequent transfusions, his leg was reamputated. His course was uneventful and his wound remained clinically uninfected.

His record was selected for it indicates some of the points on which the medical officer must make his decisions as to treatment and evacuation. The primary fact, as pointed out by the workers in the Mediterranean Theater, is that with major injury blood is lost. It continues to be lost until the wounds are débrided and, as will be presented by Dr. Prentice, it continues to be lost even though it may not be obvious by signs of external bleeding. The second fact is that any casualty with a reduced blood volume has spent his reserve and tolerates poorly movement, changes in position, morphine, and often the passage of time. A man may leave the battalion aid station apparently in good condition and reach the hospital a desperate problem in resuscitation.

There is no true "golden period" today. The wound continues to exert a deleterious effect until it is débrided (Beecher). All wounds need débridement as early as possible. With antibiotics, open treatment of wounds and tetanus prophylaxis, men rarely died from infection in Korea, particularly not infected wounds of the extremities. They died from hemorrhage and injury to vital organs. The "golden period" is therefore a relative term and, in terms of mortality, should be directed toward the time required to obtain hemostasis and correct the blood volume deficit. Infection is, without doubt, a contributing cause to the mortality in abdominal wounds and these patients deteriorate more rapidly with the prolonged passage of time before correction of their circulatory and visceral defects.

Triage rests on the premise that the greatest good must be accomplished for the greatest number under the varying conditions of warfare.

In establishing guide posts for officers performing triage, certain principles should be kept in mind: first, the purposes of the Medical Service, to support the fighting soldiers and to provide every conceivable support for the seriously injured casualty; second, the principles of care of the wounded man.

The principles involved in the care of the individual casualty include the following:

1. Life takes precedence over limb, function over anatomical defect.
2. Mechanical defects may occur which threaten life or limb.
3. Hemorrhage is the chief cause of death once a casualty reaches medical attention. Casualties with a reduced blood volume tolerate movement poorly. When possible, hemorrhage must be controlled and transfusion instituted before the patient is evacuated.

4. Serious infections develop slowly in the face of antibiotic therapy except in casualties with bowel perforations.
5. The undébrided wound continues to increase in size (infection and fluid extrusion) and continues to exert a deleterious effect on the entire body. This effect can only be reversed by débridement. Nature débrides all wounds as a slough but requires weeks to do so.
6. At the division level, therapy and evacuation must go hand in hand. Movement prior to transfusion or control of hemorrhage may be fatal. Such decisions are basic in the therapy and practice of triage.

With these principles in mind, let us establish our priorities for triage and surgical intervention. These may be listed as follows:

Priorities of Triage and Surgical Intervention

Top Priority: Mechanical correction of defects which immediately endanger life.

1. Control of external hemorrhage.
2. Relief of intracranial pressure.
3. Closure of sucking chest wound or tension pneumothorax.
4. Control of internal hemorrhage.
5. Relief of respiratory obstruction.
6. Relief of cardiac tamponade.
7. Shock, coma, or evisceration places any casualty in this group as regards priority of medical attention.

Second Priority: Correction of defects which ultimately endanger life.

1. Relief of progressive spinal cord pressure.
2. Definitive repair of perforations of gastrointestinal tract, genitourinary tract, or biliary-pancreatic tract.
3. Débridement of cerebral wounds.
4. Exploration of wounds of mediastinum.
5. Surgical amputations following traumatic amputation (to control bleeding and prevent sepsis).

Third Priority: Correction of defects which immediately endanger limb or organ.

1. Repair of major arterial wound.

Fourth Priority: Correction of defects which ultimately endanger limb or organ.

1. Exploration of ocular injuries.
2. Immobilization of compound fractures and reduction of dislocated joints.

Fifth Priority:

1. Débridement of soft tissues.
2. Realignment of fractures.

Sixth Priority: Delayed operation: Restoration of function.

1. Closure of soft tissue wounds.
2. Repair of peripheral nerves.

These priorities are self-explanatory and are based on the above principles. *Life takes precedence over limb, function over anatomical defects.* We must always repair the defect which is the most serious first. Thus when we were studying arterial injuries we found a sharp increase in the amputation rate after a lag period of 8 hours. Nevertheless, when a casualty is admitted with a perforated bowel and a perforated popliteal artery, the bowel injury must be repaired first as severe shock may interrupt the operation prior to completion and life must be protected before limb.

Specialty centers, neurosurgical and renal failure, were established in Korea and functioned well. Patients were taken to these centers by air. The paradox existed in both cases that the patients were in their best condition for transportation early. With the passage of time, both groups became less transportable.

Triage does not end with early definitive therapy. I should like to see it extended to cover a concept not only of secondary evacuation to specialty centers but to include the concept of selective evacuation followup so that the results of early treatment might be appreciated and made known to the Army surgeon and thereby to the forward surgeons while the specific need for the knowledge still existed. Thus, as we did with the arterial repairs, there could be selective management and followup of colon injuries, hepatic injuries, joint, facial or hand injuries. Mistakes could thus be appreciated and corrected within a matter of months and field medicine would progress at a tremendous rate. This is a magnificent opportunity presented only to the Armed Forces. It should be planned at this time. Better field records should be a part of the plan.

In conclusion, triage is the evaluation and classification of a casualty or casualties for purposes of therapy and evacuation. There is no more important or difficult task in the Medical Service. Triage is one of the responsibilities of the divisional medical officer. It is at the divisional level that most casualties are dying. This position, therefore, requires judgment, hard work and courage. The Medical Service and the civilian medical educators must re-emphasize this opportunity for service. In time of war, the infantryman is drafted and placed in the front lines by indirect order of the American people. His injury, deformity, or death is not of his choosing, but in defense of and by order of the American people. No higher honor can come to an American physician than that of caring for these combat casualties as a medical officer at the forward divisional level.

RESUSCITATION*

Major Curtis P. Artz, MC, Captain Yoshio Sako, MC, and Captain Alvin W. Bronwell, MC

Resuscitation, which actually means the act of reviving or restoring, is a term frequently used to describe the procedures involved in the initial management of a severely wounded man. Since the wound is a continuing injury and its effects on the entire body are dynamic ones, resuscitation may be considered as those procedures which are carried out to counteract the effect of the wound. Therefore, resuscitation is a process of continuing treatment. Since the effect of the wound starts as soon as the man is injured, resuscitation should start as soon as the man is seen. One of the effects of the wound is the loss of blood; hence resuscitation includes the administration of blood. Since tissue is damaged, resuscitation means excision of this devitalized tissue. If an airway is blocked, one of the important procedures of resuscitation is the performance of a tracheotomy in order to establish an adequate airway.

The aim of resuscitation is to restore the wounded man in order that he may withstand evacuation to the nearest surgical installation and then to further restore him so that he may safely undergo anesthesia and surgery. Some casualties with head injuries and massive chest injuries have vital organ damage incompatible with life. Others may have very serious wounds but, with judicious care, they can be evacuated to a surgical hospital where a successful repair can be carried out.

Resuscitation at Division Level

The primary aims of the battalion surgeon are to arrest hemorrhage, to prevent deterioration of the casualty's condition and to prepare him for transportation. Corpsmen are taught methods of arresting hemorrhage and of positioning for transportation; and also the value of early replacement of a deficit of blood volume with a plasma expander. Early in the Korean conflict the company aidman learned to carry small bottles of albumin for administration during litter-carry to an aid station. Later, early administration of dextran became

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popular. Dextran in plastic bags had the advantage that the company aidman could carry three or four of these units on patrol. Battalion surgeons emphasized the importance of the administration of a plasma expander as soon as a casualty was seen. Although severe blood loss may not be evident immediately after injury, a blood-volume deficiency will always occur after wounding; and therefore it is logical that immediate restoration be started.

As soon as a casualty arrives at a battalion aid station, it is the responsibility of the medical officer to make a cursory examination and to correct obvious defects. This includes the control of hemorrhage, together with closure of sucking wounds of the chest, and clearance of the airway. Simultaneously replacement therapy should be started.

Tourniquets should be used judiciously. Too frequently a tourniquet is used when a large, properly applied pressure dressing would better control hemorrhage. Application of a tourniquet often increases venous bleeding. In massive arterial bleeding and in crushed or mangled extremities, a tourniquet may be lifesaving. If necessary, tourniquets may be permitted to remain in place for 1½ hours or longer; but they may be loosened at shorter intervals if the casualty's condition will not become more critical because of risk of added blood loss. Not infrequently, a tourniquet may be used as an emergency procedure; and, after further evaluation, bleeding may be controlled by a pressure dressing. Since venous bleeding persists in spite of a tourniquet, it is always wise to put a firm pressure dressing over the wound at the same time the tourniquet is applied.

A free airway must be maintained, or hypoxia will lead to rapid deterioration. Frequently, positioning of the patient on his side and pulling out his tongue is sufficient to establish an adequate airway. In severe maxillofacial wounds, neck wounds, or wounds of the head and chest, it may be necessary to do a tracheotomy in an aid station.

Fractures must be splinted properly before transportation. An unsplinted fracture increases damage to muscle and thereby promotes further blood loss. Pain, associated with movement in an unsplinted fracture, aggravates the casualty's poor condition.

Since wounds break the barrier against bacteria, early antibiotic therapy is indicated. Whenever possible, large doses of penicillin should be given intravenously. When procaine penicillin is used, 300,000 units should be given in three or four different deposits for more rapid absorption.

The battalion surgeon is not merely a first aid man but a most important member of the resuscitative team. The care that he gives is of an emergency type, but he must also take time to institute initial procedures which will best prepare the wounded soldier for transpor-

tation. A severely wounded casualty's chance of survival during transportation can be greatly enhanced by the infusion of 2 or 3 units of a plasma expander. Hurried evacuation may lead to undue deterioration during transportation. The importance of a short time lag between injury and admission to a forward hospital is well recognized; but the battalion surgeon must weigh the advantages of a slightly prolonged evacuation time against the ability of the casualty to withstand transportation.

The most common mistakes made in division units are inadequate control of hemorrhage, inadequate splinting, overdosing with morphine, and hasty evacuation not allowing time for proper preparation of a casualty for transport. It is recognized that, in a rapidly moving type of warfare at the battalion level, the heavy flow of casualties may prohibit a medical officer from administering ideal care. At all times, however, his aim should be to put a casualty in the best possible condition for transportation in the shortest period of time.

Resuscitation at a Forward Surgical Hospital

Resuscitation at a forward surgical hospital may be divided into three phases: preoperative, operative and postoperative.

Preoperative Resuscitation

As soon as a wounded soldier arrives at the hospital, the surgeon must perform the same examination as was carried out at the battalion aid station. He should determine that hemorrhage is controlled and that there is an adequate airway. He should immediately start transfusion of blood if indicated. Nasal oxygen is of value if cyanosis is present, if there is a depressed respiration, a chest wound or massive blood loss. Blood should be started through a 15- or 17-gauge needle; it may be necessary to use two or three transfusions simultaneously. If a large amount of blood replacement is anticipated, it is wise to expose an accessible vein surgically and tie in a cannula. When it is difficult to find a suitable vein, a 13-gauge needle may be inserted into the femoral vein and a long segment of plastic tubing threaded into the inferior vena cava. The needle can be removed immediately allowing the plastic tubing to remain in place. This tubing should be removed after 24 hours or clots may form, giving rise to pulmonary embolism.

The rate of administration of blood is most important. Blood volume deficiency should be replaced as rapidly as possible. In severely wounded patients who are admitted with a blood pressure too low to be obtained by the usual cuff method, it may be necessary to start blood in three or four veins and give it at a rate of 100 cc. or

more per minute. As soon as the blood pressure has risen to 80 systolic, the rate of administration may be retarded.

It is difficult to determine the real value of intra-arterial transfusion. It is generally accepted that the value of this type of transfusion is the increased rapidity with which blood can be administered. A review of the experiences with casualties who had marked blood volume deficiency at the 46th Surgical Hospital showed that the average rate of administration by the intra-arterial route was 88 cc. per minute. In a comparable group of wounded soldiers, the rate by vein was 70 cc. per minute. No attempt was made by the observers to achieve an absolute maximum rate of infusion by either method. No definite conclusions could be drawn from this very limited experience. However, the impressions gained were that blood by the intra-arterial route was of no more value in the resuscitation of patients in deep oligemic shock than was blood by the intravenous route, provided it was given at the same rate by both methods. It was observed that the blood replacement in the small series of similarly wounded soldiers was accomplished as rapidly by multiple intravenous route as it was by the intra-arterial route. Further data and controlled experience must be obtained before the real value of intra-arterial transfusion can be ascertained.

Regardless of route of administration, many transfusions given in a forward hospital must be infused under pressure. Pumping air into the bottle of blood is the presently accepted method. Air embolism is a grave inherent danger in this procedure. In Korea, during 1952 and 1953, five deaths were reported from this procedure as a result of air embolism.

Transfusion must be continued until the casualty is ready for operation. It is most difficult to decide when a casualty's blood volume has been replaced to the extent that he can best tolerate anesthesia and surgery. Unless continued hemorrhage is present and operation is necessary to control this hemorrhage, a wounded soldier should be in the best condition possible before being subjected to the operative procedure. The value of adequate preparation of a patient has frequently been emphasized in elective civilian surgery. Likewise in the surgery of trauma, the casualty withstands the operative procedure better if he is properly restored before the operation. This means that his blood volume deficiency must be replaced to near normal levels. It is common to underestimate the amount of blood that has been lost. Redressing is done in the chain of evacuation by nurses and corpsmen; hence the surgeon does not see the large quantities of blood that may have exuded from the wound. His guides to adequacy of restoration consist of blood pressure, pulse rate and output of urine. If sufficient blood has been provided to permit good periph-

eral circulation, it will be indicated by the blood pressure. The adequacy of visceral blood flow can be estimated by the flow of urine. In severely wounded soldiers, a catheter should be inserted in the bladder in order to observe the output of urine. If a casualty excretes urine at the rate of 30 to 40 cc. per hour, adequate replacement can be assumed. Normal blood pressure does not always mean adequate replacement. A wounded soldier usually requires one to two units of blood after his systolic blood pressure has risen to 100.

Surgeons with experience in forward areas are able to judge blood requirements by the size and character of the wound and the adequacy of restoration by general appearance and color of the conjunctiva. In the absence of hemo- or pneumothorax, injury to the central nervous system, or anoxia from blockage of the respiratory passages, hypotension usually means deficiency in blood volume. Replacement should be completed as rapidly as possible; however, it may require a few hours. Sometimes a surgeon observes that hemorrhage is occurring as rapidly as blood is being replaced. Blood should then be started through two or three veins and the casualty should be placed on the operating table immediately.

In some patients with extensive wounds, slow blood loss will continue throughout the preoperative period and the blood pressure will rise very slowly. There may be a tendency to hold these patients in the preoperative section too long. It is useless to continue to replace blood endlessly when it is being lost almost as rapidly as it is being infused.

In the presence of slow, continuous hemorrhage, it is usually possible to infuse 3 or 4 units of blood rapidly, and then start the operation. If the delay is too great prior to operation, the patient may require 8 or 10 pints of blood before operation. He then will require about 10 pints of blood during the operative procedure and the total amount of blood administered will exceed 20 pints. In casualties who have received 18 or 20 pints of stored blood, a deficiency in the clotting mechanism may occur and fatal oozing from all wound surfaces may result.

A casualty is usually ready for operation when his systolic blood pressure reaches 110 and his pulse rate has fallen to 120. Frequently it is difficult to select the optimum time for operation. When the systolic blood pressure reaches 100 or 110, he may be moved to X-ray. If he is properly resuscitated, the movement will not cause a fall in blood pressure. On the other hand, if the casualty has an appreciable blood volume deficiency, a fall in blood pressure will occur when he is moved. This appears to be an additional criterion by which a surgeon can judge the adequacy of preparation for operation.

A simple tilt table was devised by the Surgical Research Team in Korea. The table was made of wood with a platform of a size convenient for holding a litter. The platform was suspended in such a manner as to have a fulcrum in the center, thereby enabling adjustment of the degree of tilt. By tilting the casualty's head up 30 degrees and observing his condition and blood pressure, the surgeon could obtain some indication as to the adequacy of restoration. If, by sufficient transfusion, a casualty was properly prepared for surgery, he could withstand a tilt of his head up 30 degrees for 10 minutes. If his condition deteriorated and his blood pressure fell, however, it was a good indication that additional blood was required. By general observation, surgeons experienced in resuscitation of the severely wounded can usually tell when a patient is ready for surgery. In questionable cases, on the other hand, the tilt table helps to determine the adequacy of the circulation.

Control of hemorrhage is a real problem in severely wounded casualties. In vascular injuries of appreciable extent, it may be possible to cut down on the vessel under local anesthesia above the site of injury and then apply an artery clamp. If there is generalized oozing, an improved pressure dressing may suffice. Concealed hemorrhage in a casualty's abdomen or chest may be the cause of failure of response. When there is a wound in that area, careful attention should be given to the size of the abdomen. A rapidly expanding abdomen may mean serious intra-abdominal hemorrhage.

A thorough search must be made for respiratory complications. Severe hypotension may be due to air or blood in the chest or to cardiac tamponade.

Resuscitation During Operation

During the operative procedure the surgeon must constantly estimate the amount of blood the patient is losing and make sure that it is replaced. Patients who have large wounds, particularly of the abdomen, chest or arteries, should have two large needles or cannulas well anchored in the veins in order that blood can be given rapidly under pressure through multiple portals. When several areas are injured there is constant oozing until the initial surgery is carried out. To minimize blood loss the operative procedure should be performed as expeditiously as possible. When feasible, in casualties who have multiple wounds two surgical teams may work in different areas to lessen the time of anesthesia and operation.

The surgeon should always be near the patient during the induction of anesthesia because of the possibility of cardiac arrest. During the last 6 months of the Korean war 14 cases of cardiac arrest were

reported in forward hospitals and all but 2 of these casualties died. After the removal of the endotracheal tube at the termination of operation, it is important to clear the airway.

Resuscitation During the Postoperative Period

Continued restoration and careful observation is an important part of resuscitation during the postoperative period. Too frequently the surgeon feels that he has restored a casualty's blood volume, through adequate procedure, and then he expects an uneventful recovery without further therapy. However, in patients with multiple severe wounds complications are common. It is imperative that the patient be examined frequently for continued blood loss, atelectasis and collection of blood in the chest. Careful recording of the blood pressure and hourly measurement of the output of urine are essential guides to therapy. A patient who is hypotensive after operation and does not excrete urine probably has a blood volume deficiency which requires further replacement. Among 138 severely wounded soldiers, 18 of the 61 requiring a total of 5 to 10 pints of blood in their first 24 hours after surgery were given more than a pint of blood postoperatively. Of those needing 10 to 35 pints of blood, in a more severely wounded group, over half were given more than 2 pints of blood in the immediate postoperative period.

Most casualties who are hypotensive after surgery require additional blood. On the other hand, there are some few whose compensatory mechanisms have been damaged by anesthesia and they will not respond to further resuscitative fluid therapy. Such wounded soldiers may be supported by norepinephrine. However, the most important and most frequent cause of postoperative hypotension in injured soldiers is an insufficient amount of circulating blood volume. Transfusion after operation should be performed with caution. Frequent auscultation of the chest is essential for signs of pulmonary edema. As long as a casualty's blood pressure is below 80 systolic and he is not excreting urine, he has need for additional blood; therefore, overtransfusion is unlikely.

Continued oozing may occur in patients who have had from 18 to 20 pints of stored blood. No one knows what deficiency in stored blood prevents natural clotting. Sometimes such a deficiency may be replaced by fresh blood. Severe oozing occurred in one casualty who received 39 units of stored blood. This oozing did not cease until after 6 pints of fresh type O blood had been administered.

As soon as a casualty's blood volume is restored to near normal levels, electrolyte solutions and water should be administered.

MONDAY AFTERNOON SESSION

Summary

Since the wound is a continuing insult to the body, resuscitation must be a continuing process. Restoration should begin as soon as the patient is seen and continue throughout the preoperative, operative and postoperative phases of the patient's care.

DISCUSSION OF PAPERS ON PREOPERATIVE TREATMENT OF BATTLE CASUALTIES*

LIEUTENANT COLONEL CARL W. HUGHES, MC

About all that I can add to what Colonel Lindsey has had to say about evacuation is further praise for the helicopter pilots. Actually, some nights when it was so dark that the bats wouldn't fly, one would hear a Bell helicopter coming in the distance. When they flew on such nights we knew that they were bringing in very severely injured patients. The helicopters often had to land by use of jeep, truck, and ambulance lights.

I want to emphasize further the thought brought out by Colonel Lindsey regarding the use of surgeons in the forward aid stations and clearing stations. I had occasion to see a number of trained surgeons come in to the theater each expecting to be given a hospital assignment where he could utilize his training by doing operative surgery. It seemed extremely unfair to the surgeon to send him up forward to work in an aid station or clearing company. Early, I felt it was a waste of a trained surgeon. Now, I am convinced that the use of a trained surgeon in the forward station was far more beneficial to the patient than many of us realized.

I have little to say on triage except that I would like to clearly emphasize my feeling for the need of a trained, experienced person in each hospital to supervise triage, to follow through surgery, and be available for consultation postoperatively. Such a man need not necessarily perform surgery but his presence would be extremely important.

Dr. Howard mentioned the priority of a bowel and popliteal artery injury saying, of course, that the bowel injury takes priority for surgery. I readily agree with Dr. Howard, but I only want to make the point that when one does have such injuries it is quite often possible to utilize two surgical teams and do both operations at once.

Major Artz made it clear, and I readily agree, that we cannot separate surgery from resuscitation since surgery is a part of resuscitation. I would, however, question the necessity of passing a plastic catheter through the femoral vein into the vena cava in order to give

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intravenous fluids. I realize that such a catheter in the femoral vein must be placed in for a short distance in order to keep it from being accidentally pulled out. If placed into the vena cava I wonder about the possibilities of thrombosis and embolism. Normally, I feel that one should be able to do a percutaneous puncture of the femoral vein or the femoral artery and avoid most cut-down procedures. We were fairly successful in using the femoral vein and femoral artery for transfusions and failed to get into any difficulties, except that when the needle or the patient moved about too much, there was apt to be a hematoma at the needle puncture site.

As far as intra-arterial transfusion is concerned, I would like to mention that very good use can be made of the exposed artery which is often seen dangling from the extremity of injured patients, particularly those with traumatic amputations. The artery, being constructed as it is of stronger tissue than the muscle, is often dangling and visible and can be readily recognized and utilized by inserting a Webster cannula or a size 13 or 15 needle directly into the artery to replace the blood by way of the artery from which it was lost. We used this method a number of times as well as intra-arterial transfusion into the femoral artery. We did feel that using the exposed artery was an excellent method of transfusing. I feel that most of us in the theater tended to underestimate the need for blood in many patients even though some received 40 to 50 pints of blood. Many of them still had need for blood when taken to surgery.

Major Artz mentioned the use of the urinary output as an indication of the condition of the patient. We also used this method of evaluation but found it was more indicative of the condition of the patient with abdominal injury than those with extremity wounds.

We made it a habit to give intravenous glucose whether blood was going to be required or not. If blood was started and glucose could be started concurrently, the patients received both and if necessary blood was also given in more than one port. I raise the question as to how valuable intravenous glucose was to these patients who had been in shock, whether or not it played any part in decreasing the number of patients developing renal shutdown.

Mention has not been made here of the use of norepinephrine. I think most of us realize that it does not have much, if any, place in resuscitation. However, we have used it in some cases preoperatively and found in some instances that it did improve the blood pressure. Some feel that when a patient is in profound shock that the vasoconstrictor mechanism has undergone its maximum vasoconstriction and the use of norepinephrine is then ineffective. We did find norepinephrine of value postoperatively. I am speaking of the postoperative period as a part of resuscitation. We have used norepine-

phrine during that period until the patient became refractive to it and died in spite of additional blood and plasma expanders.

We found some patients who, during preoperative resuscitation, apparently reached their point of maximum benefit and passed that point of maximum benefit before we realized it and became worse instead of better. This seemed to be especially true of patients with abdominal injuries with bowel wounds who were no doubt developing peritonitis or had well advanced peritonitis at that time.

ANESTHESIA FOR COMBAT CASUALTIES ON THE BASIS OF EXPERIENCE IN KOREA*

Robert D. Dripps, M. D.

Because of the type of warfare in Korea during the 18 months preceding the armistice, treatment of the battle casualty was almost ideal. There was prompt evacuation, ample supply of whole blood, rarely were peak loads a problem and personnel, equipment and supplies were adequate generally. The mortality and morbidity figures set in Korea may never be equaled. Valuable lessons were learned, however, and possibilities for improvement in care of the combat casualty still exist. In this paper the Korean experience will be analyzed from the standpoint of anesthesia.

Korea did not turn up new data on the anesthetic management of the wounded. The basic problems involved were merely re-emphasized, and one had the disturbing impression that mankind must relearn hard-won lessons from individual experience rather than build on knowledge previously gained. A few quotations from the British Medical Research Council's Special Report No. 26 entitled "Traumatic Toxemia as a Factor in Shock" (14 March 1919) make this clear. "The surgeon experienced another disappointment. If his measures were sufficient to put the soldier into a state that justified operation, this procedure produced a relapse.—A great deal of the bad effects were to be attributed to the anesthetic. Chloroform had long been recognized as dangerous, but it was more evident that ether and other anesthetics were far from harmless. Gas and oxygen was the least noxious and with its wider adoption postoperative shock greatly diminished."

The severely wounded soldier is inordinately susceptible to narcosis regardless of the agent or technic selected. Prior to anesthesia he presents a picture of apathy and depression suggestive of decreased central nervous system function. He appears to be partially narcotized already. In such a patient small amounts of central nervous depressant drugs evoke a response out of proportion to the size of the dose administered. "Normal" dosage regimens will cause death sufficiently frequently to drive this point home to the tyro. The pro-

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longed postoperative sleep of many of these patients tends to support the above. The physiological basis for this susceptibility is not completely understood. It is undoubtedly bound up with the numerous factors responsible for shock and hence has humoral, endocrine, toxic, hemodynamic and psychic aspects, to mention a few.

Experiences in World War I also emphasized the hazard of moving the combat casualty, the necessity for parenteral fluids, the problem of the optimal time after resuscitation for surgical intervention and the question of how much to do at that time. These are the crucial questions which World War II revived and which were again noted in Korea. Unless atomic or hydrogen bombs bring physiologic changes peculiar to them, one can expect future conflicts to pose essentially the same problems.

From the standpoint of "choice of anesthesia" one can set down the following generalities.

Preoperative Medication

The use of morphine to relieve pain, to prepare an individual psychologically for operation and to reduce the amount of additional drugs needed for anesthesia has been traditional. Yet many investigators have recorded the untoward reactions of man to morphine. Its ability to impair the normal compensatory response to circulatory stress is well documented. The prolonged action of a single dose can be shown readily. Such side actions as nausea, vomiting, urinary retention and constriction of smooth muscle in the biliary and respiratory passages are undesirable. Because of tradition, however, it is difficult to eliminate the injection of morphine. Yet morphine has little or no place in the management of the seriously wounded. Men in shock rarely complain of pain. They do complain bitterly of thirst but this is not an indication for morphine. They may be anxious and fearful. These are not indications for morphine. Beecher has suggested barbiturates. I wonder if any drug is needed. The sympathetic attention of corpsmen, doctors and nurses does wonders. If, as anesthesia progresses and resuscitation becomes more established, large amounts of anesthetic drugs appear necessary, the intravenous injection of morphine or meperidine (demerol) may be useful.

The educational campaign outlining the possibilities of harm of morphine must be continued, for although abuse of this drug is now less frequent overdosage is still seen. Aidmen and medical officers must be made to understand the drug better. In the event of overdosage, n-allylnor-morphine appears useful in reversing both the respiratory and circulatory depressant effects. This drug, which is administered intravenously, will return respiratory minute volume towards normal within 60 seconds. Its pressor effect is not as well

substantiated at the moment but a blood-pressure-raising action has been described.

The belladonna drugs are still used and may be given intravenously as well as intramuscularly. Whether scopolamine is preferable to atropine cannot be stated with finality. The tendency of the former to produce mental aberrations is undesirable.

Choice of Anesthesia

The guiding principle for the administration of anesthesia to any patient is use of the least amount of narcotic compatible with the surgical requirements. As already stated, this is essential in the severely wounded. The susceptibility of the serious battle casualty to anesthesia enables one to provide satisfactory working conditions with 50 to 60 percent nitrous oxide in oxygen in many patients. This concentration will not produce even minimal surgical anesthesia in normal individuals, but if satisfactory results can be obtained the shocked patient has been spared the consequences of a more potent depressant. This technic deserves continued application. I used it successfully in Korea, as have others to whom it has been suggested.

It is difficult to divorce the problem of selection of anesthetic agent from a consideration of the background of the anesthetist. Fortunately, the training of physicians in the specialty of anesthesiology has increased greatly during the past decade. Specialists were available in MASH units in Korea and in installations behind these mobile hospitals. Some of these individuals were trained in one approach to the anesthetic management of the substandard patients. Others had had a different indoctrination. Until definitive data are available to prove that one agent or technic is superior to another in the management of the severely wounded it would seem wise to permit anesthetists to apply those methods with which they are most familiar. If the patient's susceptibility is kept foremost in one's thinking, this approach appears reasonable.

Those men trained primarily in the administration of thiopental soon realized that very small doses of this drug suffice. Profound depression may be produced by 25 to 50 mg. If such be the case, it is my opinion that thiopental should be abandoned since nitrous oxide with adequate quantities of oxygen will undoubtedly be all that is necessary. If more thiopental be required but the amounts still do not compare to those used in patients in good physical condition, this fact must constantly be remembered lest overdosage result. Supplementation with nitrous oxide-oxygen is almost invariable.

Beecher has stated that the induction of anesthesia with ether alone is safe in the seriously wounded. Yet I have produced severe hypo-

tension in battle casualties with this drug in apparently very light planes of anesthesia. According to recent studies the safety of ether so far as the circulation is concerned lies in its ability to mobilize epinephrine and norepinephrine from adrenal medulla and sympathetic nerve endings. If this be prevented totally or in part, ether is a potent circulatory depressant. Probably in certain seriously wounded patients such mobilization is reduced.

Observations by Zweifach and Chambers of the greater tolerance of dogs to blood loss during cyclopropane as compared to ether are corroborated by Crooke's statement during World War II that "the best anesthetic used in our shocked patients was cyclopropane," and the data of Hershey and Rovenstine on the value of cyclopropane in the management of patients with recent severe hemorrhage. I believe that this drug has a place in the anesthetic management of the battle casualty and that it does not deserve the neglect of military planners.

Unless it can be shown that some such technic as the use of a continuous drip of norepinephrine will maintain adequate circulation during spinal anesthesia, this method of pain relief probably has no place in the management of the seriously wounded. The circulatory alterations produced by spinal anesthesia would seem contraindicated for such patients.

For intra-abdominal operations in substandard patients, bilateral intercostal block can provide excellent muscular relaxation in light planes of general anesthesia. The block can be performed after the patient is put to sleep so that the multiple needle sticks are not objectionable. Other forms of regional anesthesia also have a place if dilute solutions are used and overdosage with its threat of hypotension is avoided. An 0.5 percent solution of procaine is adequate for infiltration anesthesia. For nerve block a 1 percent solution should suffice.

The "curare" group of drugs proved of great value in Korea; d-Tubocurarine and succinylcholine were most frequently used. These substances permitted rapid intubation of the trachea, and provided muscular relaxation for varying periods of time when this was essential. Patients in shock tended to react to succinylcholine with an exaggerated degree of muscular fasciculation. Occasionally this motor activity resembled clonic convulsions. It is possible that this represented a diminished amount of plasma cholinesterase. This deserves study as one of the derangements associated with shock.

Illustrations of some of the principles discussed above are presented in figures 1 to 10.

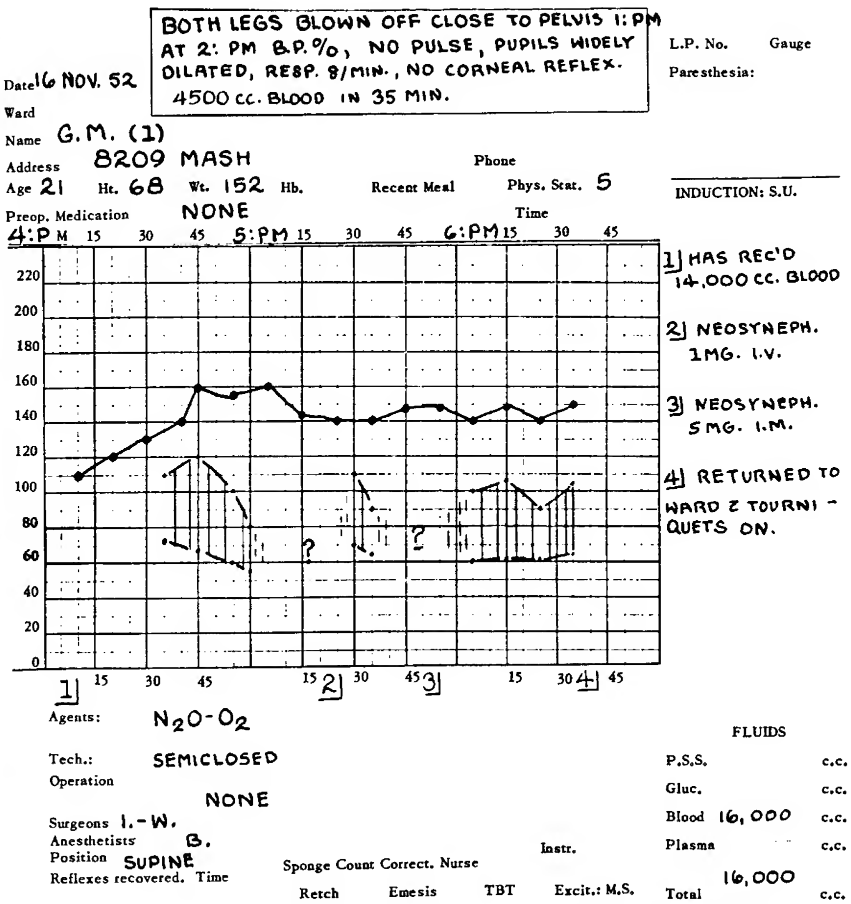
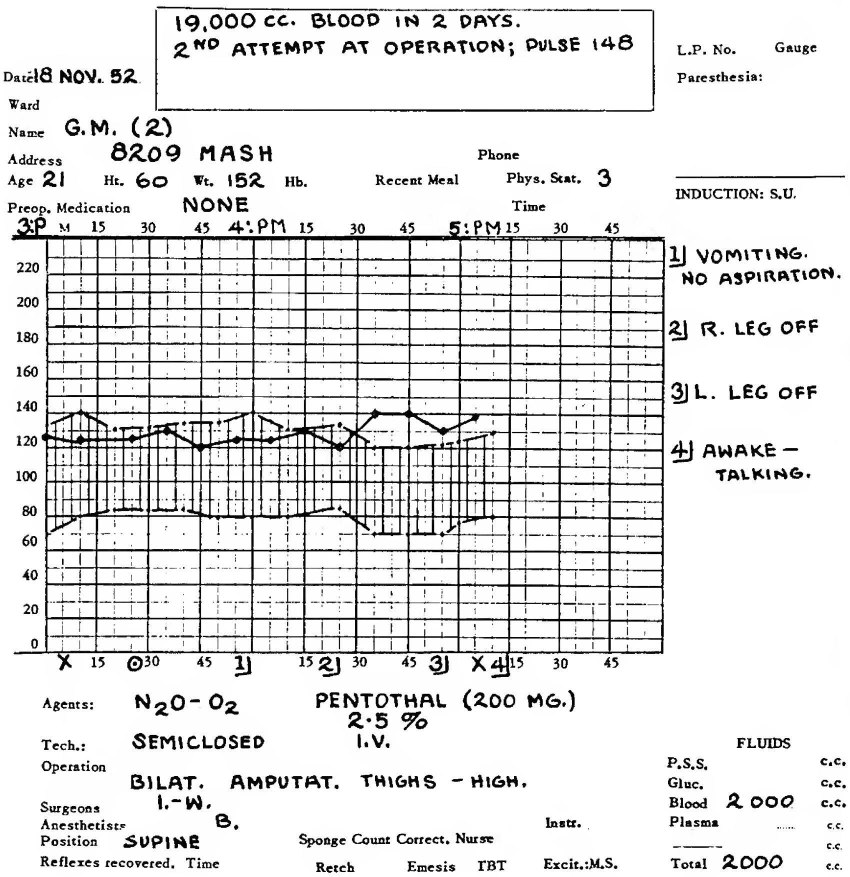


FIGURE 1. A 21-year-old American soldier with both legs blown off by a mine. On the left side the loss was close to the pelvis; on the right the loss occurred at the junction of the upper and middle third of the femur. Despite heroic transfusion therapy consisting of 14,000 cc. of whole blood in 2 hours and with a preanesthetic blood pressure of 110/70 and a pulse rate of 111, attempts at anesthesia with nitrous oxide-oxygen (60:40) and attempts to prepare the wounds for débridement brought complete collapse of the circulation. Operation was canceled.

Suggestions for the Future

War in the future may well involve many nations and many geographic areas. Civilian as well as military casualties can be expected. Infants, children and the aged and infirm may require anesthesia. National differences in electric current, terminology, coloring of gas cylinders and the like should be anticipated and efforts at standardization made. Furthermore, the earlier habit of the Armed Forces of limiting anesthetic equipment and supplies should be changed. Anesthesia is now an established science and art. As such it functions

better if a variety of agents and technics are available. Fortunately, none of these are bulky and space for shipment or storage should not prove a problem.


19,000 CC. BLOOD IN 2 DAYS.
2ND ATTEMPT AT OPERATION; PULSE 148

L.P. No. Gauge
Paresthesia:

Date 18 NOV. 52
Ward
Name G.M. (2)
Address 8209 MASH Phone
Age 21 Ht. 60 Wt. 152 Hb. Recent Meal Phys. Stat. 3
Preop. Medication NONE Time
INDUCTION: S.U.

3:PM 15 30 45 4:PM 15 30 45 5:PM 15 30 45

220 200 180 160 140 120 100 80 60 40 20 0

X 15 ⊙30 45 1) 15 2) 30 45 3) X 4) 15 30 45

1) VOMITING. NO ASPIRATION.
2) R. LEG OFF
3) L. LEG OFF
4) AWAKE — TALKING.

Agents: N_2O-O_2 PENTOTHAL (200 MG.) 2.5 %
Tech.: SEMICLOSED I.V.
Operation BILAT. AMPUTAT. THIGHS — HIGH.
Surgeons I.-W.
Anesthetists B.
Instr.
Position SUPINE
Sponge Count Correct. Nurse
Reflexes recovered. Time
Retch Emesis TBT Excit.:M.S.

FLUIDS
P.S.S. c.c.
Gluc. c.c.
Blood 2 000 c.c.
Plasma c.c.
c.c.
Total 2000 c.c.

FIGURE 2. The soldier discussed in figure 1 was re-anesthetized 48 hours after the first attempt. He had received a total of 19,000 cc. of whole blood, had a blood pressure of 124/70 and a pulse rate of 126. High bilateral amputation of both thighs was successfully completed under extremely light anesthesia with small amounts of pentothal and nitrous oxide-oxygen.

1. *Equipment*

The Table of Supplies should be broadened to include equipment recognized to be of value in anesthesia. Kits should be provided which would contain several types of laryngoscope blades, oral and nasotracheal tubes of various sizes including those for infants and children, oral and nasal airways, syringes and needles for regional anesthesia, connectors and small parts for anesthesia machines. The

machines should be standardized so that cylinders from various countries can be interchanged. Portable operating tables should be standardized so that voltage differences in different countries will not be an obstacle. Suction equipment not requiring electricity should be provided.

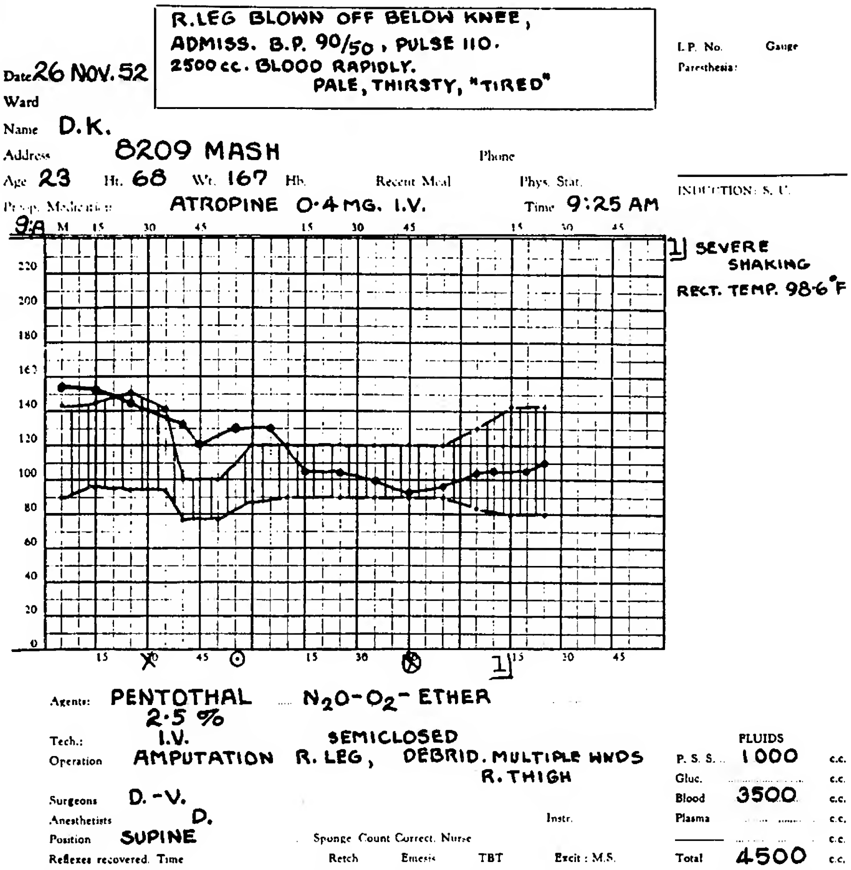


FIGURE 3. A 23-year-old white male who was pale, "tired" and thirsty despite 2,500 cc. of whole blood. His right leg had been blown off below the knee by a mine. Blood pressure was 144/90 and pulse rate 154. The relatively high blood pressure suggested maximal efforts at compensatory vasoconstriction, and warned of hypotension with induction of anesthesia. This occurred as pentothal (200 mg.) was administered slowly over a 10-minute period. A more seriously ill casualty might have had an even greater fall in blood pressure. Note the reduction in pulse pressure following anesthesia.

A field anesthesia record should be provided which will fit into the EMT jacket and accompany the casualty. This record should have sufficient blank space to permit recording of essential data.

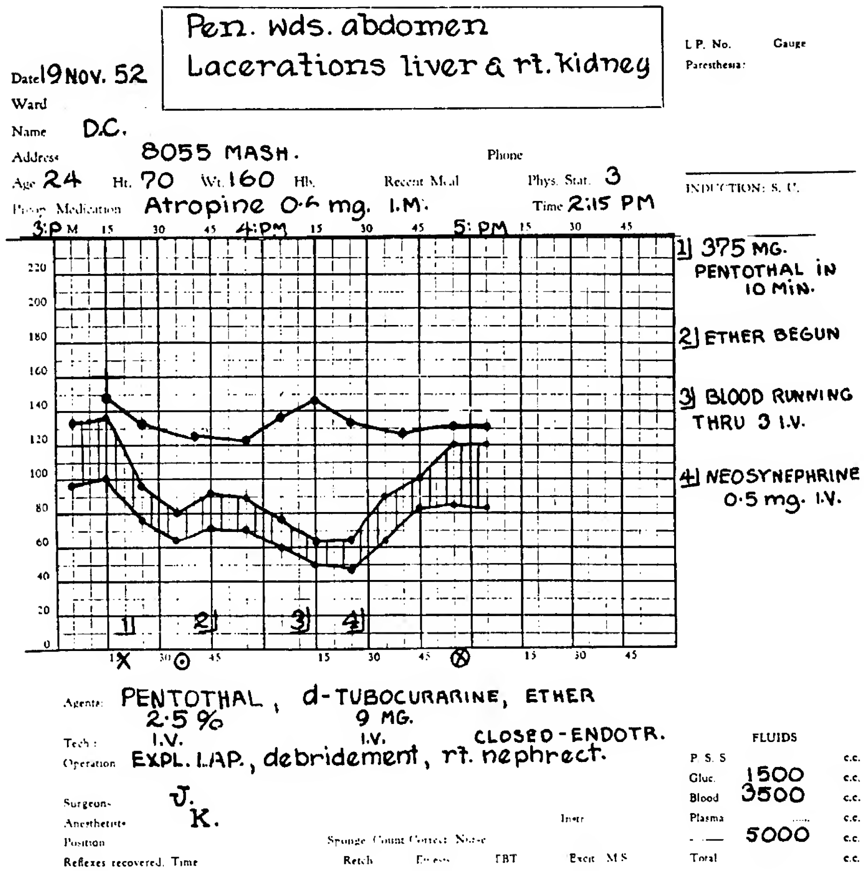


Figure 4. A 24-year-old white male with multiple penetrating wounds of the abdomen. The pre-anesthetic pulse rate of 148 and the high diastolic pressure should have warned of circulatory instability. Induction of anesthesia was followed by a sharp decrease in blood pressure and a narrowing of the pulse pressure. The addition of ethyl ether vapor at 4 p. m. brought a further reduction in arterial pressure. Five thousand cc. of fluid was administered during the operation. A pressor drug, neosynephrine, appeared of value.

2. *Supplies*

Drugs should be increased in scope. Various "curare" drugs, pressor agents such as norepinephrine, adrenolytic or ganglionic blocking drugs, and various local anesthetics should be provided. Cyclopropane should be available. All gas cylinders should conform to the international color code to avoid the confusion and dangers noted during World War II when, for example, a green American cylinder contained oxygen and a green British cylinder contained carbon dioxide.

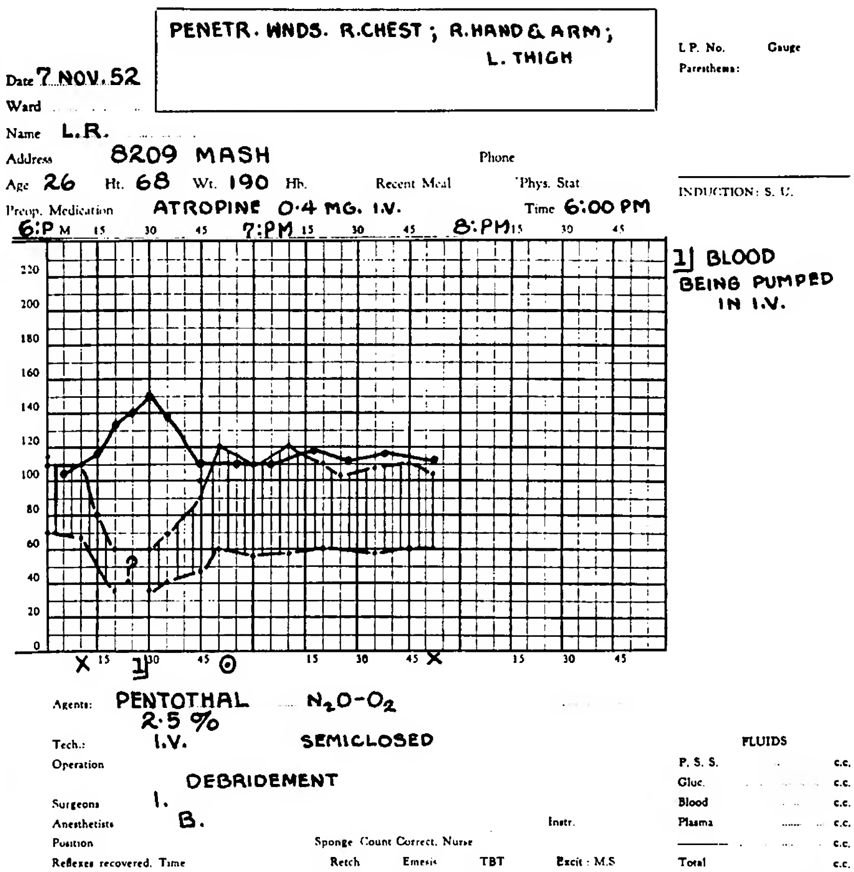

PENETR. WNDS. R.CHEST; R.HAND & ARM; L. THIGH
L.P. No. Gauge
Parenthesia:
Date 7 NOV. 52
Ward
Name L.R.
Address 8209 MASH
Phone
Age 26 Ht. 68 Wt. 190 Hb. Recent Meal Phys. Stat
INDUCTION: S. C.
Preop. Medication ATROPINE 0.4 MG. I.V. Time 6:00 PM
6:PM 15 30 45 7:PM 15 30 45 8:PM 15 30 45
220 200 180 160 140 120 100 80 60 40 20 0
1] BLOOD BEING PUMPED IN I.V.
X 15 1] 30 45 ⊙ 15 30 45 X 15 30 45
Agents: PENTOTHAL 2.5 % N_2O-O_2
Tech.: I.V. SEMICLOSED
Operation DEBRIDEMENT
Surgeons I.
Anesthetists B.
Instr.
Position
Sponge Count Correct. Nurse
Reflexes recovered. Time Retch Emesis TBT Excit: M.S
FLUIDS
P. S. S. c.c.
Gluc. c.c.
Blood c.c.
Plasma c.c.
c.c.
Total c.c.

FIGURE 5. A 26-year-old white male with penetrating wounds of the right side of chest, right hand and arm and left thigh. This soldier did not appear to be seriously wounded. The hypotension which followed the onset of anesthesia was related to a gross overdosage of pentothal. A technician anesthetist administered 1.5 gm. of this drug in 15 minutes in an effort to facilitate tracheal intubation. One cannot blame the drug in this instance so much as the way in which it was administered. It was fortunate that a fatality was averted.

3. Organization

Much more would have been learned in Korea had mature, experienced anesthetists been assigned to FECOM and the 8th Army as consultants. The recent provision of a senior consultant in anesthesia in the Office of The Surgeon General has been a valuable step. In future wars consultants for field units should be made available. These men should be urged to administer anesthesia in forward units such as the surgical hospitals so as to have first-hand knowledge of the problems involved, and thus to be able to advise and train others more authoritatively.

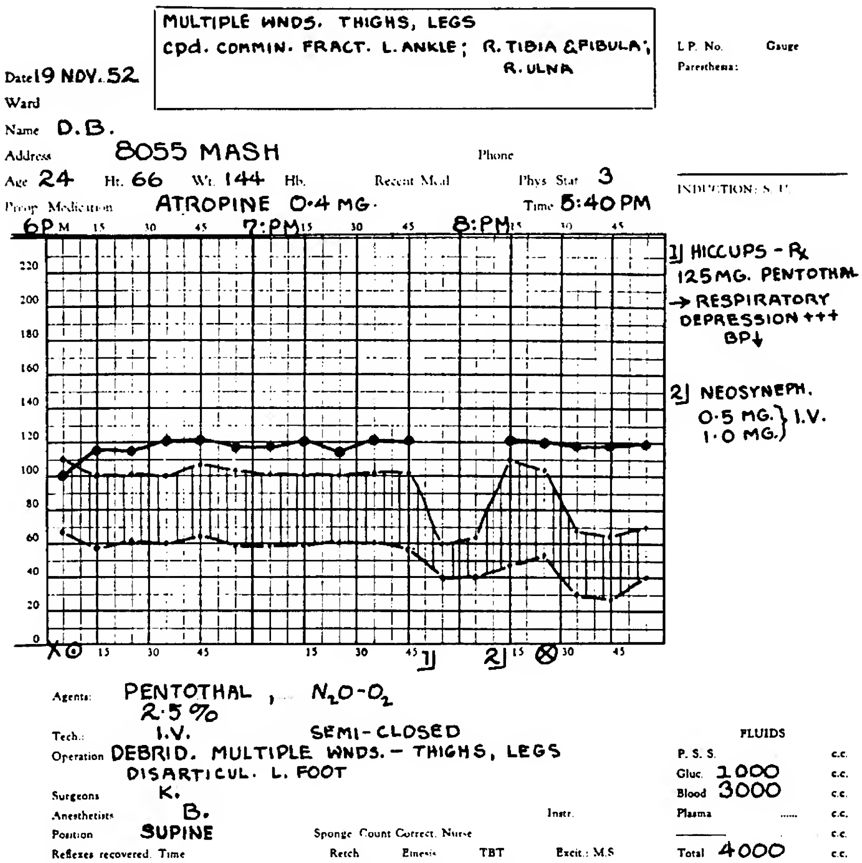


FIGURE 6. A 24-year-old white male who was not in shock prior to anesthesia. After 2 hours of a perfectly satisfactory pentothal-nitrous oxide-oxygen anesthesia this patient began to hiccup. The anesthetist failed to realize that pentothal can accumulate in the body as anesthesia progresses. Its rate of destruction (about 15 percent per hour) is slower than many recognize. Injection of 125 mg. of pentothal, a dose which was well tolerated at 6 p. m., caused profound respiratory and circulatory depression at 7:50 p. m.

As Tovell has pointed out in "The History of Anesthesiology in the European Theater of Operations" and as I stated in my report to The Surgeon General in December of 1952, the greatest need for thoroughly qualified physician anesthetists is in forward medical installations. Decisions requiring judgment and experience are required in these units. If improperly made, the casualty will suffer.

A monthly report of the anesthetics administered, the physical condition of the anesthetized subjects, and the results obtained should be required from each medical installation. It is a platitude to state that war is wasteful. Yet in reviewing the medical opportunities

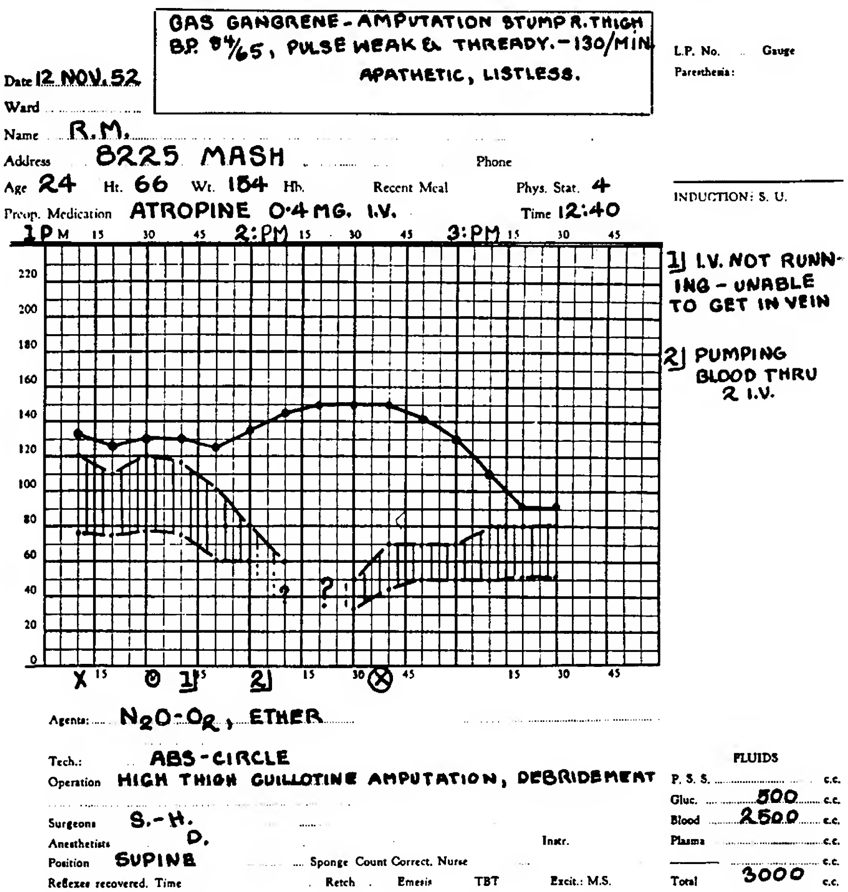


FIGURE 7. A 24-year-old white male with gas gangrene in a right thigh amputation stump. Inadequate fluid therapy was partially responsible for the severe hypotension noted. Ether anesthesia, however, although only mid-first plane according to clinical signs, appeared to contribute to the profound circulatory collapse.

presented by combat—whatever the field of interest—one is impressed with how much is lost, unrecorded and unappraised. How important, for example, it would be to have data on deaths related to anesthesia; to have records of different methods of management of various types of casualties; to know the course of the soldier who ultimately develped post-traumatic renal failure, i. e., how long did hypotension exist, what kind of blood was administered; what were the incidence and sequelae of vomiting during anesthesia of the soldier with a full stomach. These and dozens of other problems demand solutions. All personnel should be indoctrinated in the necessity of collecting data. Anesthetists should be stimulated to observe, record and make sugges-

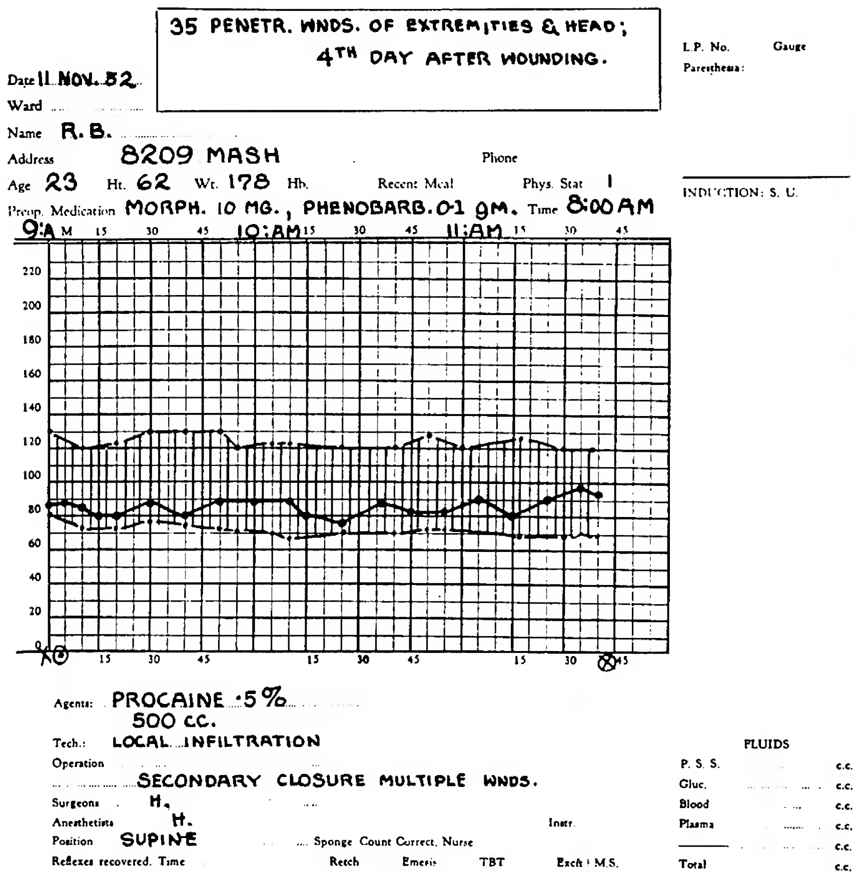


FIGURE 8. A 23-year-old white male who did well during secondary closure of 35 penetrating wounds of the head and extremities. Operation, which required almost 3 hours, was performed under dilute procaine 0.5 percent. The total volume of solution was high, but it must be remembered that this amount was given over a long period of time.

tions based on their experience. Such an approach should increase interest among anesthetists but must be initiated at top levels.

Under "Organization" should also be listed the provision of facilities for photography, wherever possible in color. This can preserve experiences which otherwise are lost.

Finally, on the basis of World War II and Korean experience, facilities for research should be planned in advance. The Surgical Research Team in Korea justified itself beyond expectation.

4. Education and Training

Manuals and training films for military anesthetists should be prepared now rather than waiting for an outbreak of hostilities. The

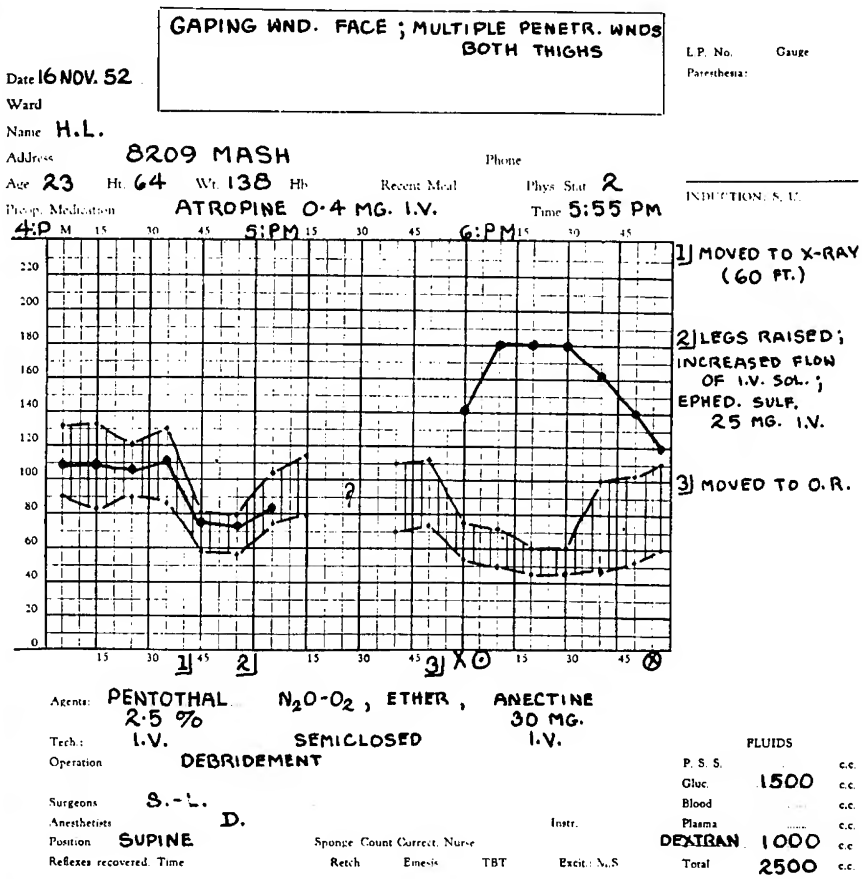


FIGURE 9. A 23-year-old white male with a large gaping wound of the face and multiple penetrating wounds of the thighs. On admission this individual was pale, thirsty and had a blood pressure of 90/70. After what appeared to be successful resuscitation with parenteral fluids, the patient was moved about 60 feet for X-ray examinations. Blood pressure promptly fell from 130/86 to 80/60 (The adverse effect of motion on the blood pressure was commonly seen.) After additional efforts at resuscitation, induction of anesthesia was also followed by a decline of blood pressure from 112/72 to 60/45.

Subcommittee on Anesthesia of the National Research Council might be given this responsibility in consultation with experts who have served in World War II and in Korea. A sufficient amount of knowledge has now accumulated to make such manuals and films of value. Basic aspects of resuscitation, pharmacology and physiology should be included.

5. Projects for Research in Civilian and Military Centers

A number of problems bearing on the anesthetic management of battle casualties require investigation. These include the effects of anes-

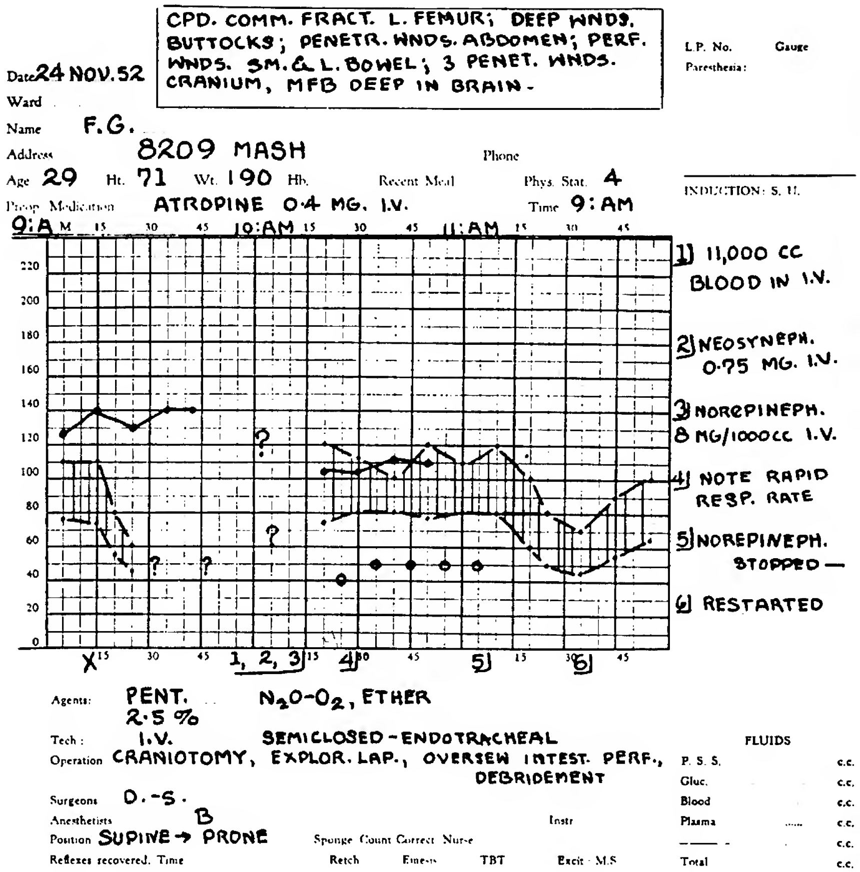


FIGURE 10. A critically injured 29-year-old Negro with penetrating wounds of the abdomen, skull and lower extremities. Onset of anesthesia was followed by profound hypotension. Neosynephrine was of no value, but norepinephrine by constant intravenous infusion restored blood pressure to normal limits. Each time that the drip of this drug was slowed hypotension occurred.

thetic agents and technics on the adrenal cortex and medulla; the effects of anesthetic agents on blood flow to various tissues and organs; the value of adrenolytic or ganglionic blocking drugs in the management of hemorrhagic or wound shock; the role of vasoconstrictor drugs such as norepinephrine in the management of patients in shock of varying types; the utility of hypothermia as an adjunct to anesthesia; the value of intra-arterial transfusion; the etiology and therapy of uncontrolled oozing during operation: the physiologic alterations in the circulation related to motion and change of position.

In addition, one must anticipate whether such future possibilities as atomic or hydrogen bomb warfare, combat in the Arctic, or use of

chemical warfare agents will pose specific problems for the anesthetist.

Finally, clinical evaluation of such new technics as transtracheal injection of topical anesthetics, continuous drip of pentothal, continuous drip of succinylcholine and the use of trichlorethylene is needed. This should be done by a number of competent individuals with subsequent discussion and analysis of results by a group. Again the Subcommittee on Anesthesia of the National Research Council is suggested as an advisory body.

One is uncertain as to whether to recommend pharyngeal irritation to produce vomiting in casualties who face anesthesia and who have full stomachs. This deserves exploration.

The severe, shaking chills seen during the immediate postoperative period appear undesirable. Their cause and prevention should be considered. These may be related to the effects of narcotics on temperature regulation, to the administration of a large volume of cold blood or to exposure during operation.

The establishing of tests to assist in the selection of the ideal time for initial surgical intervention merits thought. As a rule this decision involves the art of anesthesia and surgery at the moment rather than the science of these branches of medicine.

It is no exaggeration to say that World War II provided great impetus for the growth of the specialty of anesthesiology. There are now many trained individuals available and more are being trained each year. Research work in anesthesia is progressing in a number of laboratories. The Armed Forces should benefit from this growth and development in any future conflict. But maximal benefit will come only if plans are made in advance.

TUESDAY MORNING SESSION

20 April 1954

MODERATOR

Colonel William S. Stone, MC

THE X-RAY SERVICE IN AN ARMY AREA SURGICAL HOSPITAL*

COLONEL HARRY L. BERMAN, MC

Our experience in the Korean conflict tended to crystallize some of our notions about our problems in the field of military roentgenology. We entered this struggle after a decade of singular and conspicuous progress in the science of medicine. The specialty of radiology, being intimately associated with the other branches of medicine, naturally shared in the advances. However, because of the incomplete status of development of our newer military X-ray equipment, our entry into Korea was made with World War II equipment and perhaps with somewhat outdated concepts by many physicians as to the practice of roentgenology.

Since practically all aspects of military roentgenology revolve about equipment, let us consider that item first, including a little about its background. Military field X-ray equipment is designed to produce roentgenograms of satisfactory diagnostic quality, while retaining the features of minimum weight, adaptability to a limited power supply, and sturdiness to withstand the ravages of adverse environmental effects and rough handling. The ideal machine is one in which an extremely rapid exposure may be made, just as in the case of a camera, to minimize the effect of motion and the resultant blurred detail on films.

The time of exposure bears a definite relationship to the number of milliamperes which an X-ray machine delivers. For example, if a certain examination requires an exposure of 100 milliampere-seconds with a given voltage, the same effect is produced by a machine operating at 200 milliamperes for one-half second as by one operating at 25 milliamperes for 4 seconds. It should be quite clear that the chances of motion on the part of a patient, especially a semicomatose one, are much greater with an exposure of 4 seconds than with one requiring a half-second.

However, those machines designed to deliver the higher amperages are excessively heavy, unwieldy units with power requirements far beyond those which field generators can meet. Consequently, for field

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

use an X-ray machine within allowable limits of weight and power requirements will have definite restrictions as to output in amperage, and the price paid for that sacrifice is a prolonged exposure time.

At the beginning of World War II it was anticipated that the demonstration of fractures and the localization of foreign bodies would constitute the major portion of the radiological work in the forward areas and that this could be done mainly by fluoroscopy alone. Furthermore, it was expected that film would be in short supply, necessitating resort to fluoroscopy. It was believed too at that time that definitive surgical care would be given in fixed-type hospitals further to the rear, where conventional X-ray equipment including all accessory items would be installed.

The World War II unit was accordingly built to meet the needs of the forward area installation. It was constructed to operate with one tube for both fluoroscopy and radiography. It was capable of a maximum output of 85 kilovolts and 30 milliamperes. This of course was more than adequate for fluoroscopy which is normally performed at 3 to 5 MA. The table is a steel frame which was expected to support a litter for a top (fig. 1). The casette holder could be adjusted so that a fixed grid might be interposed between the part examined and the film. If necessary, the tube could be turned to one

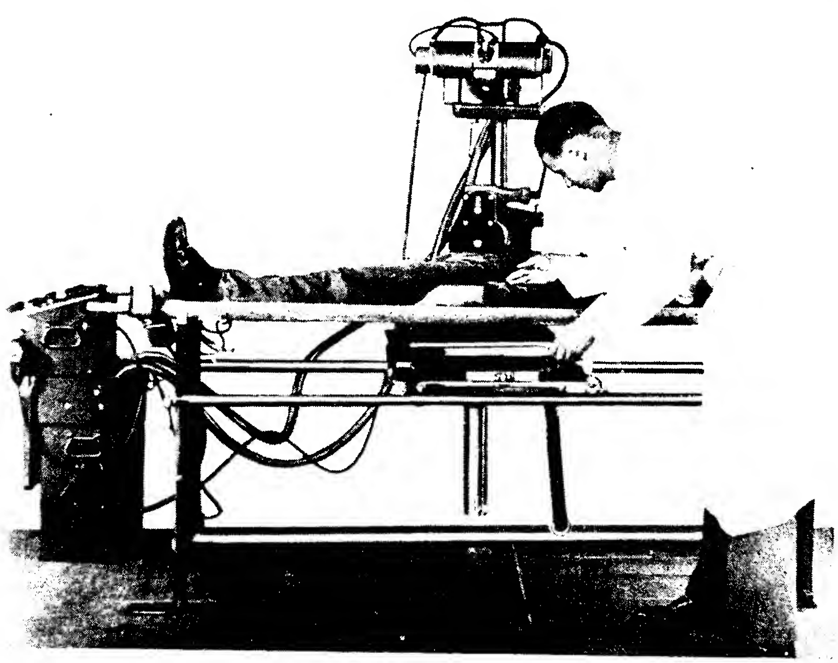


FIGURE 1. World War II field x-ray unit.

side for the examination of litter patients on the floor or adjusted for vertical radiography of the chest.

Fluoroscopy with this unit is done by swinging the tube beneath the table top, but it is cumbersome and awkward. Patients could not be readily examined in both the horizontal and vertical positions without a time-consuming shifting of the apparatus, and the fluoroscopic screen held in a practically rigid position could not be moved around freely for the examination of different areas.

The unit was a rugged, well-built piece of equipment requiring very little maintenance, and generally it might have served the purpose for which it was intended, as the problem of medical care in the forward areas was originally envisaged. However, subsequent experience proved the fallacy of that concept. The definitive care of the so-called nontransportable patient was instituted in mobile hospitals in the forward area, a practice which was extended in the Korean conflict. The nature of the work there required films which the surgeon wished to see and which could serve a permanent record. Foreign body localization assumed less importance than was expected. Furthermore, there was a demand for routine roentgen procedures, such as barium enemas, gastrointestinal series, etc., none of which were easily performed on the World War II unit. Some of the more enterprising radiologists improvised certain embellishments to facilitate some of the radiographic procedures, but it seemed obvious after the war that the development of a more serviceable unit was in order.

After careful study in the postwar period, it was decided to build two types of field x-ray machines: (1) a small one, light in weight and readily mobile for use in hospitals in the forward areas; and (2) a larger unit containing most of the features of a conventional machine for use in the fixed hospitals in the communications zone.

The former, capable of a maximum output of 85 KV and 15 MA, was intended for use in such installations as the Mobile Army Surgical Hospitals and the evacuation hospitals. It first made its appearance in Korea in the latter part of 1951. Up to that time and for some time afterwards the World War II unit was used in the medical installations in Korea and in most numbered hospitals in Japan.

This unit, shown in figure 2, has several features which are a definite improvement over the World War II unit. The table, serving as its own packing case, has a sliding top which can be set quickly and easily in either the horizontal or vertical positions. The tube is easily positioned over the table for radiography or under it for fluoroscopy. The unit has a reciprocating Bucky diaphragm; that is, one which oscillates

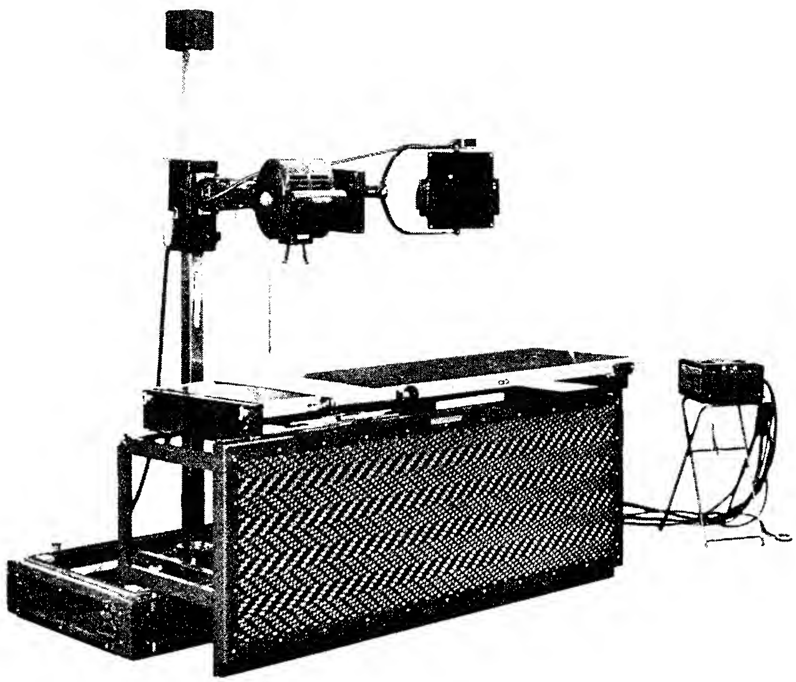


FIGURE 2. 15 MA field x-ray unit.

back and forth. A lightweight portable tube-stand equipped with large casters is part of the set and permits its use as a bedside unit.

In spite of these improvements, it is felt that changing from a 30 MA to a 15 MA machine was a retrogressive step. Benefits to be derived from the increased flexibility of an x-ray machine should not be gained at the expense of the exposure time and at the risk of motion of the patient. If the purpose of the new machine was to demonstrate only fractures or metallic fragments, then it presented no advantage over the old machine. If it was to facilitate the performance of routine and diverse procedures, the prolongation of the exposure time nullified the effects of improvements in equipment. It was almost impossible to immobilize large individuals and irrational or semi-comatose patients for the required time of exposure. The same problem held in the case of head examinations, stereoscopic films, and in gastrointestinal series in which the situation was aggravated by the fact that the stomach and duodenum are normally in motion.

After a 6-month trial the first 2 units in Korea were converted to 30 MA machines by using cable converter kits along with the tube, transformer and control stand of the World War II unit. This was a definite improvement and at present constitutes the best we have for

the forward installations. Although it still leaves much to be desired, considering the type of work done in those hospitals, it is capable of a satisfactory performance.

The larger unit, operating at a maximum of 100 KV and 100 MA, has all the features of a modern, conventional radiographic and fluoroscopic machine (fig. 3). It has a hydromatic motor-driven tilt table, two tubes with rotating anodes—one for fluoroscopy and one for radiography, a fluoroscopic screen with a spot film device, and a movable Bucky diaphragm. It differs from conventional equipment in that its transformer utilizes a gas, sulfur hexafluoride, as an insulating medium, instead of the usual transformer oil. This gas is odorless, nontoxic, noninflammable and has a density about five times that of air. All wires and cables are of the "plug-together" type and can be quickly connected and disconnected. The machine has been designed to reduce weight whenever possible, but it is still too heavy for use in the forward area installations. When used in the field away from a community power supply, it requires a 10 KW generator for a power supply.

It is possible to combine certain items from both field units and thereby have an intermediate machine with a high output in milliamperage, while retaining the features of moderate weight and

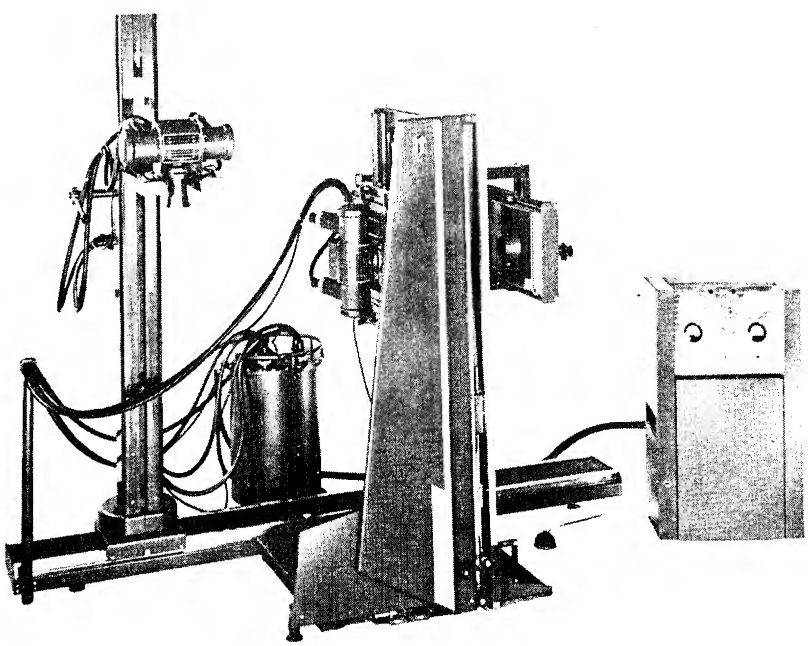


FIGURE 3. 100 MA field x-ray unit.

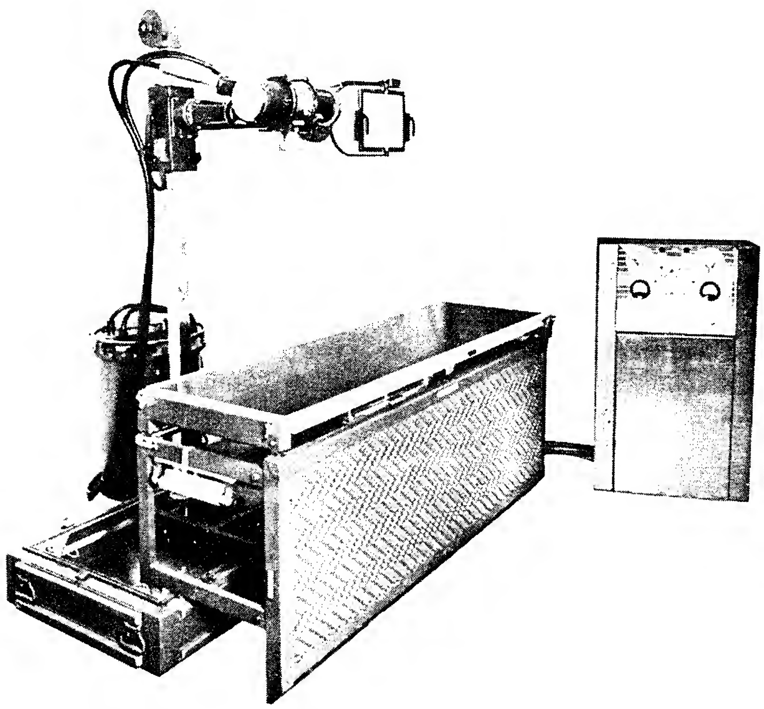


FIGURE 4. 100 MA field x-ray unit with lightweight table.

mobility (fig. 4). The control stand, transformer and rotating anode tube of the large unit are combined with the lightweight table of the smaller unit. The power requirements of the large unit, namely, a 10 KW generator, remain unchanged. This combination was not tried in Korea. It should have a field test.

Of the accessory items of equipment the most important is that concerned with film processing. This consists of a stainless steel processing tank with two inserts for the solutions and a water-conditioning unit to maintain the temperature of the solutions at 68° F. regardless of the environmental temperature. The film can be dried in a field dryer (fig. 5) after processing.

The chemical processing of films was a very perplexing problem. For reasons difficult to determine, whether because of the complexity of the equipment or the inertia of the technicians, the temperature-conditioning unit did not work. As a consequence, the temperature of the processing solutions varied with that of the environment. The problem was especially acute in the winter and summer when extremes of environmental temperatures occur. Thus, films were too often processed in solutions which were too warm or too cold.

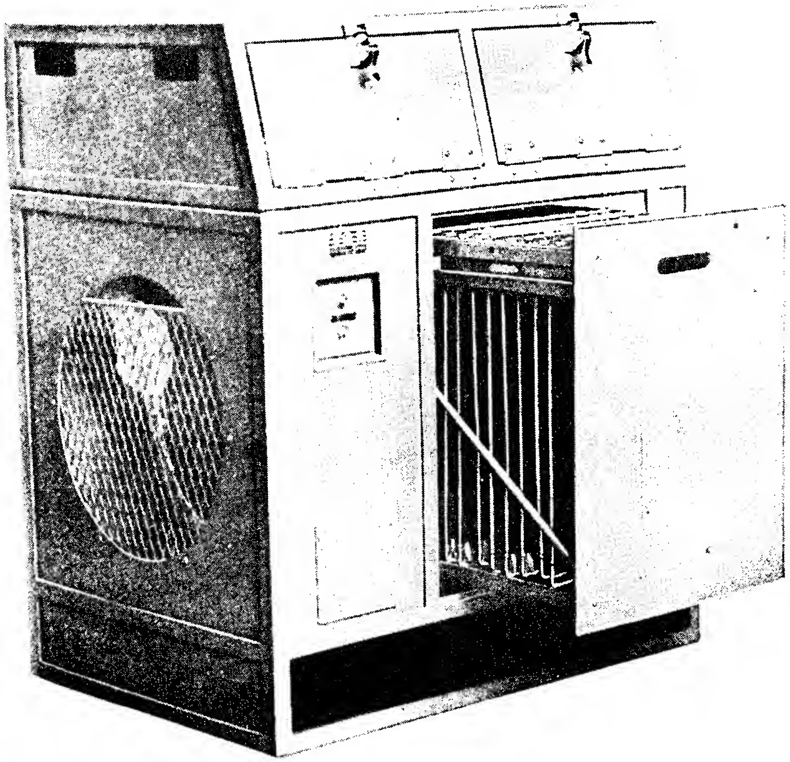


FIGURE 5. Field dryer.

The processing of films presents a problem from another aspect. Frequently, patients were immediately evacuated after initial examination in the MASH. An envelope of wet, incompletely developed films went with the patient. These were subsequently of little use, although they might have provided important information. There is need for a rapid developing and drying process for field use.

The Land-Polaroid process was tried in Korea but not with especially gratifying results. This equipment makes use of a special cassette with paper instead of transparent film. After exposure of the film, it is placed in an electrically operated processing device and developed for 1 minute, following which the device is opened and the film is immediately available for use. In radiographs prepared by this method, the detail is not too satisfactory in the thicker parts. This method of radiography has great possibilities but requires further study.

No standard stereoscopes of the Wheatstone type were available in Korea. There was a crying need for stereoscopy, especially in the management of battle casualties with head and eye injuries. The

need was met by using a 90-degree prism obtained from the periscope of salvaged tanks. This represented an inexpensive and economical solution.

So much for equipment. Now I should like to say a few words about the problem of radiation protection. Initially there was considerable laxity on the part of all personnel with respect to protection from radiation. There was a tendency ascribed to expediency to crowd auxiliary services, such as x-ray, laboratory, pharmacy and admitting room, into as compact a space as possible. As a result, a large number of people were being constantly exposed to radiation while performing their normal duties. I saw a roentgenologist reading films seated 3 feet away from an x-ray machine in constant use. Recently he wrote me that his white blood count was low. The practice on the part of technicians of standing close to an x-ray machine while making an exposure, was very common. Occasionally, one saw a small piece of lead, set for some strange reason about 3 feet from the floor, behind which the technician stood during an exposure.

Although sheet lead was available in Korea, its use for protection barriers was negligible until its importance was stressed. Towards the end of 1952 the situation in this regard showed considerable improvement. The hazard of radiation to personnel must be constantly emphasized and unremitting attention must be devoted to appropriate protective measures. Figure 6 demonstrates a desirable arrangement of an x-ray department for a field-type hospital.

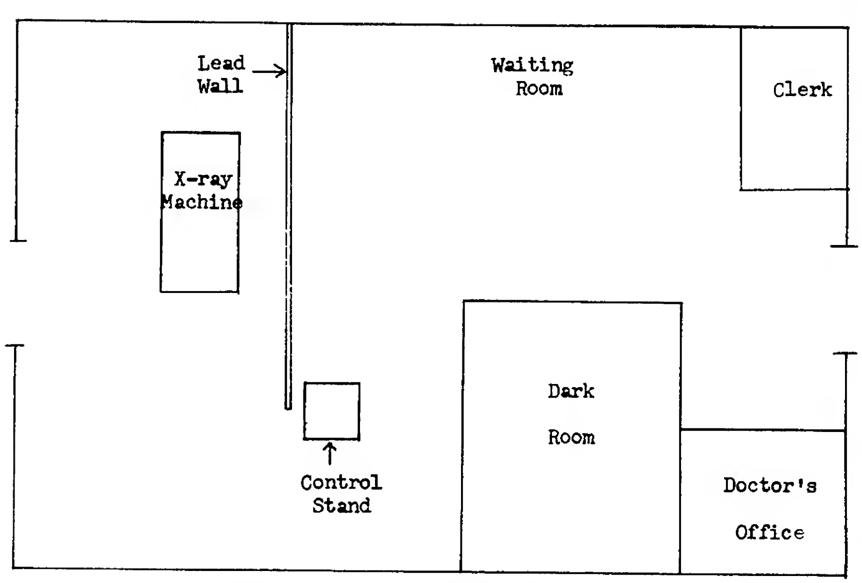


FIGURE 6. Arrangement of x-ray department in tent for field use.

The problem of protection raises the question as to the location of the x-ray department in the forward area hospitals. Its best location is near the admitting room, so that it lies along the normal flow of patients through the hospital. Protective lead or sand-bag barriers should be interposed between the x-ray machine and personnel who must be in its vicinity. Where these cannot be provided, a minimum of 10 yards on all sides should separate the x-ray department from the other parts of the hospital. As a mandatory minimum for the x-ray personnel the presence of a protective barrier as shown in figure 6 is essential.

Many of the problems relative to protection and technic stemmed from the fact that no trained roentgenologists were assigned to the Mobile Army Surgical Hospitals. It is an accepted fact that x-ray films and roentgen studies generally are better in a hospital with a roentgenologist than in one without. Initially it was felt that no roentgenologist would be needed because of the fact that the patients were all traumatic in type, and it was desired to keep the number of nonsurgical personnel at a minimum. In a sense, this is a reversion to the broken-bone, metal-fragment brand of roentgenology of olden times, but the need for having a minimum of personnel may be an overriding consideration. During the latter part of 1952 competent roentgenologists were assigned to the MASH's and undoubtedly contributed substantially towards an improved standard of roentgenology. Most hospitals used them in the combined status of roentgenologist and admitting officer or officer in charge of the preoperative ward. The MASH commanders generally preferred to rotate their surgical personnel through the preoperative ward and not have a full-time roentgenologist. They felt that they would like to have a consulting roentgenologist visit them from time to time to discuss their diagnostic and technical problems.

There was an adequate supply of generally competent, well-trained enlisted technicians. Most of these came from the conventional hospitals in the United States, where the handling of acute casualties is done infrequently. In the training of our technicians more emphasis should be placed on the work under field conditions and on practice with simulated casualties.

In the latter part of 1952 a field x-ray unit was installed in the clearing station of the 40th Infantry Division as a test to see if needless evacuation for minor injuries and some minor medical conditions might be reduced. The addition of this unit to a division clearing company creates certain additional logistical and technical problems for that organization. Whether or not the benefits to be gained will compensate for those problems has not been determined. The question requires further study.

Roentgenological studies in the management of the various wounds and injuries treated in the forward area hospitals contribute a great deal more than the mere demonstration of fractures and metallic fragments. The localization of small fragments of bone and metal in the brain is extremely important to the neurosurgeon, but this cannot be done without good films. The localization of foreign bodies in and about the eyes can be made with a pair of good stereoscopic films without recourse to special equipment, such as the Sweet localizer, but stereoscopic films of a severely wounded man cannot be made with a machine requiring a long exposure time. The care of chest wounds with intrathoracic hemorrhage, pneumothorax and hemopericardium requires films showing good detail. Similarly, free air and blood from ruptured abdominal viscera cannot be detected on films of poor quality. Such diagnoses are a far cry from the days of fracture and shrapnel roentgenology, and yet without this knowledge the surgeon is greatly hampered. Many other examples could be cited to show the place of roentgen studies. They need not be recounted here, but it suffices to make mention of this fact in order to point out that diagnoses are made when the index of suspicion has height and breadth.

Our forward area hospitals are now capable of performing surgery of a prodigious nature. Its diagnostic support in the field of roentgenology requires appropriate examinations, technically well prepared and competently interpreted. We have certain problems requiring further study. Our aim is to provide all the means possible to assist the surgeon.

OPERATION OF BLOOD BANK SYSTEMS*

COLONEL DOUGLAS B. KENDRICK, MC

It is the purpose of this paper to review the development of blood bank systems in the Armed Forces during World War II and the Korean war, with special emphasis on our accomplishments, inadequacies and recommendations for improvements in the system of blood supply to our fighting forces.

In the annals of military history there is probably nothing that has made a greater impact on the curing of ills and the restoration of function resulting from war wounds than the adequate and judicious use of whole blood. It is a strange paradox that, in an era of medicine that will long be remembered as the culmination of the renaissance of this great art, approximately a half century elapsed before it became generally accepted that the mortality rates from war wounds were almost directly proportional to the availability and proper use of whole blood. Although the lessons learned in World War II were convincing evidence of this concept, it remained for the Korean war to establish this principle firmly in the minds of operating surgeons and statisticians alike. It is not surprising, then, that when the history of World War II is reviewed, the errors of omission, related to the inadequacy of the supply of whole blood, are so apparent.

With the knowledge which we possess today as to the needs for whole blood for resuscitation and major surgery, it seems incredible that we could have permitted so much delay during World War II in making whole blood available to the theaters of operation throughout the world. But in all fairness to those concerned and for the sake of the record, it should be pointed out that the supply of blood to theaters, far removed from the mainland, depends on four cardinal features: a completely closed, sterile, pyrogen-free system of collection in a container which will maintain its integrtiy; an efficient anticoagulant and preservative solution which will extend the longevity of red blood cells to meet the logistical demands; maintenance of constant temperature during shipment; and availability of sufficient long-range airplanes to permit a continuous and dependable supply of blood. These four requirements first became available in the summer of 1944, and it was

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

at that time that we began to make blood available in vast quantities from the homeland to both the European and Pacific theaters.

A brief resumé of the struggle encountered during World War II to develop a system of blood supply in active theaters, and from the United States to units in the field will help to emphasize the difficulty of trying to introduce new methods of medical management during a worldwide conflict. As early as 1940, DeGowin and Hardin had demonstrated, by shipping in planes, blood refrigerated with wet ice in marmite cans back and forth across country, the feasibility of transporting blood long distances and using it safely in recipients several days after collection.

The next important development was in the field of blood-collecting equipment. In the processing of liquid plasma, it became apparent that the successful manufacture of liquid plasma for transfusion was dependent upon the use of a completely closed system with sterile, pyrogen-free containers and collecting sets. This principle was carried over to the collection of blood for transfusion, and from it stemmed the development of sterile vacuum bottles and disposable collecting and administration sets. With the advent of these transfusion units in 1942, recommendations were made to make these sets available to all hospitals in combat areas, to replace the makeshift equipment such as open flasks and funnels filled with cotton gauze as filters. Despite repeated pleas by personnel in the Mediterranean theater for suitable blood transfusion equipment, the newly-developed equipment was not made available because the great need for blood in addition to plasma was not recognized by those in a position to provide it, and secondly, it was ruled that overseas surface shipping capacities for medical equipment were not adequate to allow for the use of disposable blood bottles in overseas theaters. Thus, makeshift transfusion equipment continued to be employed in the Mediterranean theater and the European theater until early 1944. As a result of persistent effort on the part of transfusion officers in Italy and England, and despite other handicaps, excellent blood bank systems were developed locally and blood was collected from troops in the communications zones and made available to hospitals in combat areas in each theater.

Anticipating the needs for larger quantities of blood for the invasion of the continent, the National Research Council in April 1944, recommended collecting blood in the United States and transporting it to England by air. This recommendation was opposed, and it was not until August 1944, after requirements for blood exceeded that afforded from England, that a plan was permitted to go forward to fly blood to England. This plan was quickly implemented, and within 2 weeks 1,000 bottles of blood a day, with a dating period of 14 days, were being shipped. This was quickly raised to 1,500 bottles a day. Within

a short time improved preservative solutions were developed and utilized, which made it possible to allow a 21-day dating period.

The lessons learned in the European theater of operations and Italy regarding blood shipments, delivery to individual units and the proper use of blood in the treatment of casualties were of inestimable value in the Pacific. By November 1944, through the cooperation of the Army and Navy, daily blood shipments were being made to Leyte and other islands in the Pacific, and supplies from the United States continued as the major source of blood for the Pacific until the end of the Japanese war.

Although, to many of you, the history of the development of blood bank systems in World War II may seem incongruous and woefully slow, I wish to remind you that as late as 1940 and 1941 transfusions of whole blood were done with considerable trepidation because of the frequent mishaps that resulted; furthermore, there was no standardization of equipment, and even direct transfusions were still being employed because of the fear of reactions from citrate; and the transfusion of a patient rarely exceeded the injection of 500 cc. of blood. Thus, the development of blood bank systems between 1941 and 1945 for the armed services entailed not only the investigation of suitable equipment for collecting, shipping, preserving and injecting blood, but required the indoctrination of all medical officers in the proper use of blood transfusions.

What were the lessons learned about blood bank systems in World War II?

1. To prevent contamination and permit long storage and shipment, blood must be collected under a closed system into sterile, pyrogen-free containers.

2. Storage and shipment at a constant temperature of 38° to 42° F. are essential to preserve red blood cells for the allotted 3 weeks.

3. Blood can be preserved with acid-citrate dextrose solution (Loutet-Mollison solution) up to 21 days with an expected 70 percent post-transfusion survival rate of red blood cells.

4. Low-titer, Group "O" blood was found to be relatively safe and more desirable for use in combat hospitals than group-specific blood.

5. During hostilities, blood can be collected from troops in the communications zones, but the majority of blood utilized should be obtained from the Zone of Interior.

6. To permit the proper collection of blood from troops in the communications zone, adequate supplies of transfusion equipment must be included in medical supplies in support of armies, corps and regimental combat teams.

7. In World War II the administrative control of blood bank systems developed as awkwardly as the technical procedures. In 1945, based upon a review of the blood bank system in World War II, it was recommended that in case of future conflict a transfusion branch in the Office of The Surgeon General should be established to inaugurate a whole blood procurement program. Sufficient personnel should be trained in transfusion therapy to man the various positions required.

8. In addition to the transfusion branch in the Office of The Surgeon General, there should be a Consultant on Blood and Transfusions attached to the office of each Theater Surgeon who will be responsible for the blood supply to communications zone hospitals and combat units in that theater. There should be sufficient collecting and distributing teams to collect and deliver blood in the theater, and sufficient equipment to store and process blood received from the United States.

These were the lessons learned and the recommendations made at the end of World War II. Only 5 years elapsed before we were called upon to test out the recommendations set forth in 1945.

Blood Bank System during the Korean War

In 1949, in preparation for any future national emergency, a Blood and Blood Derivatives Committee was set up in the Medical Director's Office of the Department of Defense and plans were made to make available adequate equipment for the collection, shipment and administration of whole blood as well as plasma and albumin. This Committee was responsible for developing all policy related to the needs for blood and blood derivatives for the Armed Forces. The recommendations of this Committee were implemented by the Directorate of the Armed Services Medical Procurement Agency, and consequently, during 1949 and 1950 considerable blood transfusion equipment was procured.

Thus, at the outset of hostilities in June 1950 in Korea, equipment for the collection and administration of blood was available in the Far East theater. A blood collection program was initiated promptly in Japan, and through the cooperation of troops, civilian nationals and foreign nationals as donors, the initial requirements for blood were met. By August 1950 increasing casualty rates indicated the need for much larger quantities of blood; therefore, a supplemental supply was requested from the United States. The request for whole blood was reviewed and acted upon by the Blood Committee of the Defense Department. As a result, an operational group, designated the Blood and Blood Derivatives Group, was established under the Directorate of the Armed Services Medical Procurement Agency. This

group was charged with the responsibility of securing adequate supplies of blood, obtaining equipment and supplies for shipment, processing blood and filling the orders for blood as they were received from the Far East theater. The Defense Department asked the American Red Cross to collect blood for the Armed Forces and this organization worked in unison with the blood group in meeting quotas as they developed. By using existing American Red Cross centers, Defense centers operated by ARC, cooperating blood banks working with ARC, and by the development of Armed Forces centers on military bases throughout the country, sufficient blood was collected to cover our needs in Korea, as well as to supply plasma-processing plants and albumin-fractionation plants in the United States.

For shipment overseas, only low-titer group "O" blood, collected in 120 cc. of ACD solution, was used. It was collected in sterile, pyrogen-free, vacuum glass bottles, providing a completely closed system. Blood collected in centers scattered throughout the country was transported by air lift to the Armed Services blood-processing center at Travis Air Force Base. This processing laboratory was adequately staffed with trained personnel who usually screened all bottles of blood, retyped it, re-titered it, and determined the suitability of each bottle for shipment by checking for abnormalities in appearance and volume. Storage and re-icing facilities were available to maintain an adequate supply of blood to meet the daily overseas quotas. The Processing Center also coordinated the shipment of blood overseas with the cooperation of the Military Air Transport Service.

Blood shipments were consigned to the 406th Laboratory in Japan, and this organization had the responsibility of supplying the distribution centers in Korea with their daily requirements. Blood for this purpose was available both from Japan as well as the United States; approximately 75 percent of the blood came from the Zone of Interior. It is interesting to note that although the 406th Laboratory distributed blood directly to medical installations in Japan, the supply of blood to medical units in Korea was a function of various Army medical depots in Korea, which in turn delivered to Army surgical hospitals and other installations using blood. Where supply lines were long, there were intermediate storage and supply points. It should be pointed out that in this type of blood bank system it is necessary for each depot, intermediate storage and supply point to maintain a sufficient amount of blood to permit each to meet its maximum requirements at all times. It is admittedly desirable to have the pipeline filled at all times, but multiple supply and resupply points are undesirable.

During Word War II and the Korean war there appeared to be an unlimited reservoir of blood available. In the future, because of the requirement for civilian as well as military casualties, resulting from

atomic warfare, whole blood will have to be conserved more than ever before. This can best be done by having a blood-collection and delivery system, which is a separate, complete unit, centrally coordinated and supervised and given the authority and responsibility for making blood available to using medical installations. In this manner, usage rates can be determined and stores of blood formally trapped in multiple supply points can be mobilized. During wartime it is expected that, because of the perishability of blood and unpredictable enemy action, a certain percentage of blood may become outdated. However, in planning for total war, we must revise our thinking and reduce our blood losses to the barest minimum.

Comments

With this brief historical review of the development of blood bank systems during World War II and the Korean war, it seems appropriate to recapitulate by outlining the lessons learned in Korea and the inadequacies which remain to be corrected. First I shall mention the basic principles of military blood bank systems which have been clearly established, and follow this by pointing out the inadequacies which still exist.

1. Whole blood is an essential part of the armamentarium for treating casualties produced by war.
2. The collection of blood in a closed, sterile, pyrogen-free container and shipment of it to the far corners of the globe by air are feasible.
3. By collecting blood in an optimum solution of acid-citrate-dextrose and maintaining it at a constant temperature of 4° to 6° C, it can be preserved and administered safely for 21 days.
4. Low-titer group "O" blood is more acceptable for use in combat medical units than type-specific blood.
5. Although blood can be preserved for 21 days, the need for transfusions can best be served with fresh blood, and every effort should be made to balance supply and demand so that the freshest blood possible can be used.
6. Reusable blood-shipping containers have proved to be efficient and economical. Rigid, fiber board, trunklike containers with 3-inch plastic, waterproofed insulation have been most effective in maintaining a constant temperature at fairly extreme ambients.

Inadequacies which continue to plague us in military blood bank systems are divided into administrative and technical problems.

1. *Administrative Problems*

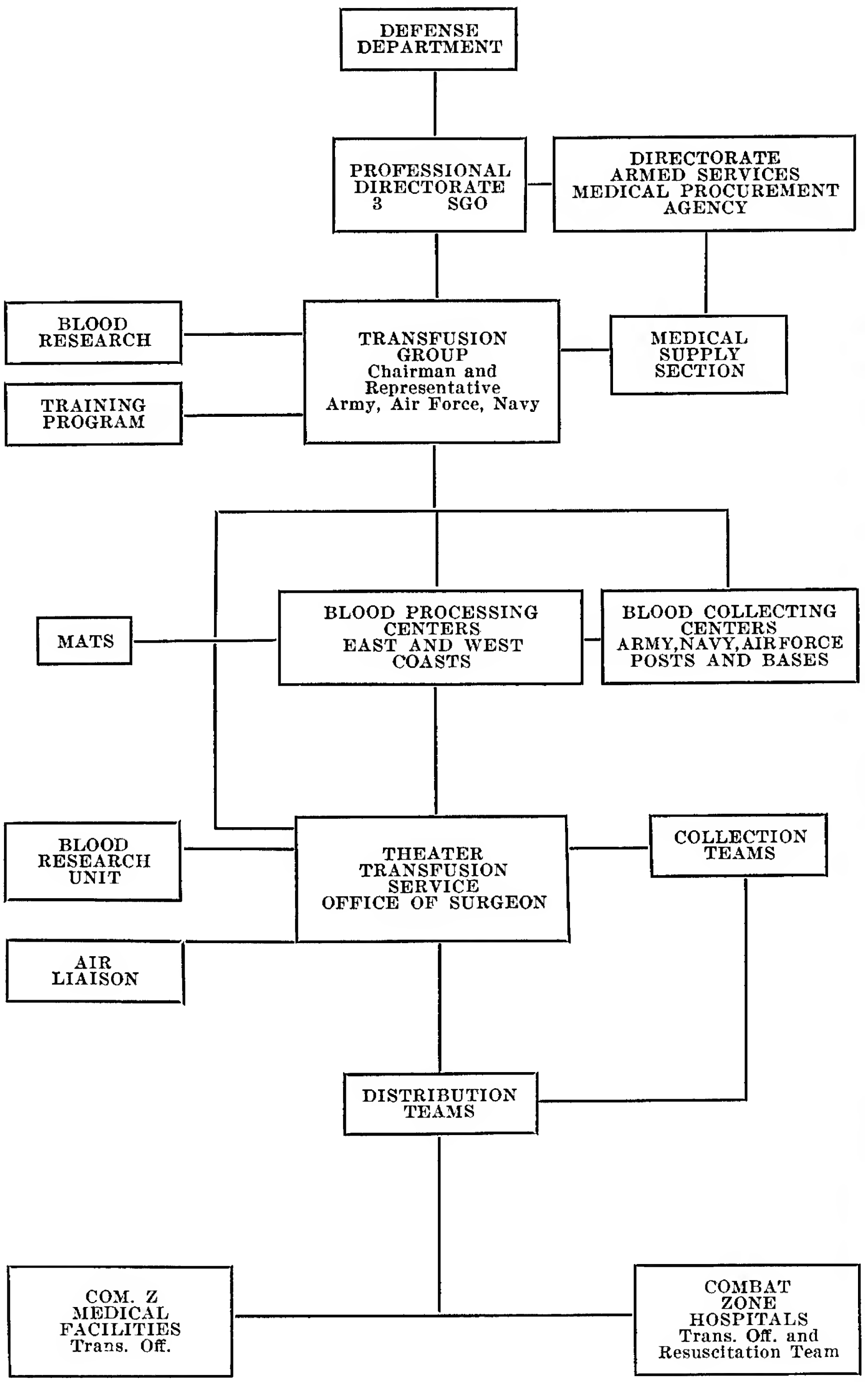
Organization of a Military Blood Bank System. Experience during two wars in the past 10 years has revealed the fallacy of not having

a well organized blood bank system established when hostilities break out. This has resulted in delays, inefficiency, greater expense and inability to capitalize on the tremendous research potentialities afforded us by the collection and clinical use in war casualties of millions of units of blood.

It is my firm conviction that the technology involved in the collection, preservation, shipment, storage, distribution and clinical use of whole blood—in other words, blood bank systems—is a *professional* responsibility. Whole blood is a rapidly perishable biological that should be treated like no other medical item that we have and, therefore, should not be placed in supply channels. Its potentialities for salvaging maimed bodies are such that the organization and personnel responsible for the blood bank system of our Armed Services should be of the highest order. Entirely too little emphasis has been placed on the organization of a Transfusion Service in the past, and it has been forced to fight for its existence without benefit of adequately trained personnel and without the backing and support of professional services. Primary support for the Transfusion Service in World War II and Korea has been afforded by the Supply Division, and proper credit should be accorded it for its constant and loyal support. However, the provisions for whole blood and the operation of blood bank systems, including distribution, are not Supply problems, but rather a professional logistic project requiring the greatest coordination of skilled professional personnel. Cognizance should be taken of this and a continuing effort made to train personnel in the laboratory phases, clinical phases and research requirements for blood transfusions, so as to organize blood bank systems in the future staffed with well trained physicians thoroughly versed in all phases of military blood banking. It is recommended that the Blood Bank System for the Armed Forces be established along the lines indicated on the following chart.

Because of the extremely limited dating period of blood and the need for highly specialized personnel to manage whole blood in all phases of its use, it seems desirable during a national emergency to place the responsibility for the blood bank system in the hands of a professional blood group that should be a part of a professional directorate, the membership of which would represent the three Surgeons General.

The Blood Group would have the responsibility for the complete operation of the Armed Forces Blood Bank System. The main functions would be to develop standard procedures of operation, establish training facilities for transfusionists, develop and provide transfusion supplies and equipment, develop and operate military donor centers, supervise research in whole blood for transfusions, operate the blood-



Proposed Military Blood Bank System.

processing centers and maintain liaison and supervision over the Transfusion Service in each theater, regulating supplies as required.

A Medical Transfusion Officer in each theater will be responsible for the Transfusion Service in his area. The local collection of blood and the storage and distribution of blood directly to using medical installations in the theater should be under his supervision. This system is not novel, nor does it lack precedent, for it proved its efficiency in Italy and France in World War II. To have blood processed and distributed as a medical supply item through medical supply channels is considered improper handling, and this function should be directly under the Theater Transfusion Officer. Distributing blood through supply depots slows up its ultimate destination, increases the requirements for blood to maintain maximum credits at each storage and supply point, and is conducive to the utilization of the oldest blood routinely. The Transfusion Officer in the theater who controls the request for blood should be responsible for its direct delivery to using hospitals—this is by far the most efficient way to balance supply and demand and reduce gross waste resulting from outdating.

To provide an efficient worldwide Blood Bank System, it is essential that the Blood Group maintain close liaison with Transfusion Officers in each theater and that standard procedures be utilized.

2. *Technical Problems*

a. Equipment suitable for collection and shipment of blood must be immediately available at the outbreak of hostilities. It is recommended that this equipment be purchased and stored, and sufficient quantities be made available in overseas theaters.

b. It is recommended that research be continued in the fields of transfusion reactions, improvement of solutions to increase red blood cell survival and improvements in equipment with emphasis on the use of plastic bags for blood (see also 2*f*, below).

c. It is recommended that technical manuals be prepared covering all phases of blood bank systems, and that medical officers be educated in the proper utilization of whole blood transfusion for resuscitation.

d. It is recommended that in the event of hostilities, the Armed Forces establish and operate their own blood-collecting centers. In this way the entire Blood Bank System for the Military can be properly controlled from point of collection through delivery to medical treatment facility.

e. It is recommended that standard operating procedures for the collection, processing, storage, shipment, distribution and proper utilization of whole blood, and technical manuals on the use of existing blood transfusion equipment be prepared for instruction purposes.

f. Plastic bags for whole blood. Plastic bags have been undergoing

tests for the past 4 years. Results of these tests indicate that plastic bags suitable for the collection, storage and administration of blood can be fabricated and used safely. Logistically, plastic bags are desirable because a bag containing 500 cc. of blood occupies only one-half the space of a bottle similarly filled. Our present blood-shipping containers will accommodate 48 bags instead of the usual 24 bottles. It is recommended that acceptable plastic bags replace bottles for the field use of whole blood and that only plastic bags be used for overseas shipment.

Summary

A brief history of the development of blood bank systems in World War II and in the Korean War has been presented. The lessons learned in relation to supplying whole blood in support of armies in combat situations have been outlined. Recommendations, based on the lessons learned in the field of blood bank systems, have been presented with the hope that from this discussion will emerge a well organized military blood bank system which will control, in time of war, the collection, delivery, and utilization of whole blood.

EXPERIENCE WITH PROCUREMENT, STORAGE, AND DISTRIBUTION OF BLOOD FROM LOCAL SOURCES IN THE EARLY DAYS OF THE KOREAN WAR*

COLONEL R. L. HULLINGHORST, MC

As indicated in the title, this paper will not be concerned with the important aspect of utilization of blood, but with a brief presentation of some difficulties encountered in establishing a blood program in a military theater faced with sudden conversion from occupation duties to active warfare. This requires a brief historical account of the general situation before proceeding to a discussion of the specific problems of: (a) formulating a general blood policy, (b) organizing the blood bank, (c) estimating requirements, and (d) reacting to critical supply shortages.

Prior to the onset of hostilities in Korea only the Tokyo Army and Osaka Army Hospitals maintained blood banks and these were sufficient only to meet their own needs. The sudden invasion of the Republic of Korea on 25 June 1950, was a shock to both tactical and logistic elements of the Far East Command.

During the following week it became obvious that medical field units were being formed within the Eighth Army in expectation of the decision by the United Nations to actively oppose the aggressors. The need for whole blood in the care of expected casualties became apparent and on 3 July the Commanding Officer of the 406th Medical General Laboratory was assigned the responsibility for establishing a blood program. Four days later, blood was delivered to the first hospital unit arriving in Korea. From that time on, no active hospital in Korea was ever without blood.

Formulating a General Blood Policy. All combat and many supporting units were being alerted. This left only a small number of service troops, military dependents, foreign businessmen and diplomats as the donor reservoir, since theater policy prohibited the receipt of blood donations from the Japanese population in the early phases. Concentration of potential donors in the Tokyo-Yokohama area, and marked depletion of troops in the vicinity of existing hospitals else-

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

where required a central collecting agency to provide blood not only to Korea, but also to those hospitals in Japan which would be receiving casualties evacuated from field units.

Only group O blood would be supplied for use in Korea. Blood of high titer was to be used for group O recipients, conserving that of low titer for administration to wounded of other blood groups. Compatibility by Rh type was to be disregarded provided the blood was acceptable in the routine cross-match.

Hospitals in Japan were expected to use blood compatible as to group and Rh factor, and were to be supplied with the necessary amount of eight basic varieties of blood.

A 21-day expiration policy was adopted, and standards of donor acceptability were those of recognized authorities (*1*, *2*, *3*), with modifications. As an example of such modifications, a set of tables was later prepared establishing the volume of blood to be collected from persons of small stature in order to deviate from the limitation of 200 cc. as the maximum blood donation approved by the Japanese Medical Association.

Organizing the Blood Bank. The importance of excellent public relations in the procurement and handling of donors was recognized early. Fortunately there emerged a full-time American Red Cross volunteer who proved competent and invaluable. The full cooperation of Armed Forces Station, the FECOM newspaper *Stars and Stripes* and of the other local newspapers (both English speaking and Japanese) was readily obtained. A corps of part-time volunteer workers were organized as receptionists, nurse's aids, clerks and chauffeurs in support of donor service. These were later supplemented by a similar staff obtained with the aid of the Japanese Red Cross when permission to accept Japanese donors was obtained.

From the assigned laboratory personnel plus three attached officers of the Army Nurse Corps there were formed a central collecting and processing unit, mobile collecting teams and a storage and courier section. An advanced blood bank depot was established in southern Japan from which local hospitals were supplied, and from which couriered deliveries were made to hospitals in the Pusan bridgehead by air as called for.

By mid-August the 8090 Blood Bank Laboratory Detachment was activated and attached to the Medical General Laboratory although qualified personnel for this supplementary unit were acquired only gradually. The Commanding Officer of the General Laboratory, however, remained the one responsible for the entire theater blood program. This position warranted the full-time utilization of a senior officer and assistant to plan and direct procurement, supervise distribution and instruct in the proper utilization of blood and blood substi-

tutes. These important responsibilities were never satisfactorily handled as additional duties.

Estimating Blood Requirements. Efforts to obtain data from World War II experience for planning blood requirements were relatively unsuccessful. The single reference available (*4*) stated that British experience in the Middle East had recommended 0.1 pint per soldier wounded in action (WIA); data from United States Forces in the Mediterranean Theater showed 0.45 pint/WIA; for planning purposes, the Whole Blood Committee of the European Theater of Operations utilized 0.2 pint per casualty (type not stated). From the 20,000 potential donors in the Tokyo-Yokohama area it was felt that at least 100 pints per day could be collected over a prolonged period—using a program of repeat bleeding at 10-week intervals (this assumption proved sound in that 60,191 pints were collected in the next 18 months).

Utilizing such planning data, it was expected that these resources would be ample for the small number of casualties expected initially from the "police action." With growing realization that a relatively major effort would be required for solution of the Korean situation, a re-evaluation became necessary. Using daily G1 strength reports, it was obvious that our forces were incurring 2.5 WIA per thousand per day. Experience during the first 5 weeks indicated that blood had been required at a ratio of 0.8 pint/WIA. Applying these factors (fig. 1) to the projected buildup of troop strength in Korea and assuming that gradually increasing military superiority would be reflected in diminishing casualty rates for our troops in November and December, a peak requirement of 420 pints per day would be required by 30 October. Based on this estimate a request was made for periodic shipment from the continental United States of that amount in excess of the 100 pints per day to be procured locally. This local procurement was continued (fig. 2) in order to provide an easily controlled cushion for sudden fluctuation in requirements. It also provided the specific types of blood for hospitals in Japan, since shipment of blood other than group O from the United States did not seem feasible.

This long-term estimate of blood requirements was subjected to frequent revision as the variations of military favor and disfavor affected our troops. The short-term casualty estimates required for a continuing evaluation of blood requirements are, unfortunately, not a recognized function of either Army or theater staffs. An attempt was made to foresee major fluctuations by daily review of theater G2 and G3 summaries. This was of some value although ultimately dependence was placed on daily reports from the medical supply depot in Korea. A sudden request for increased shipments such as from 200 to 800 pints daily was met with the 2-day reserve maintained in

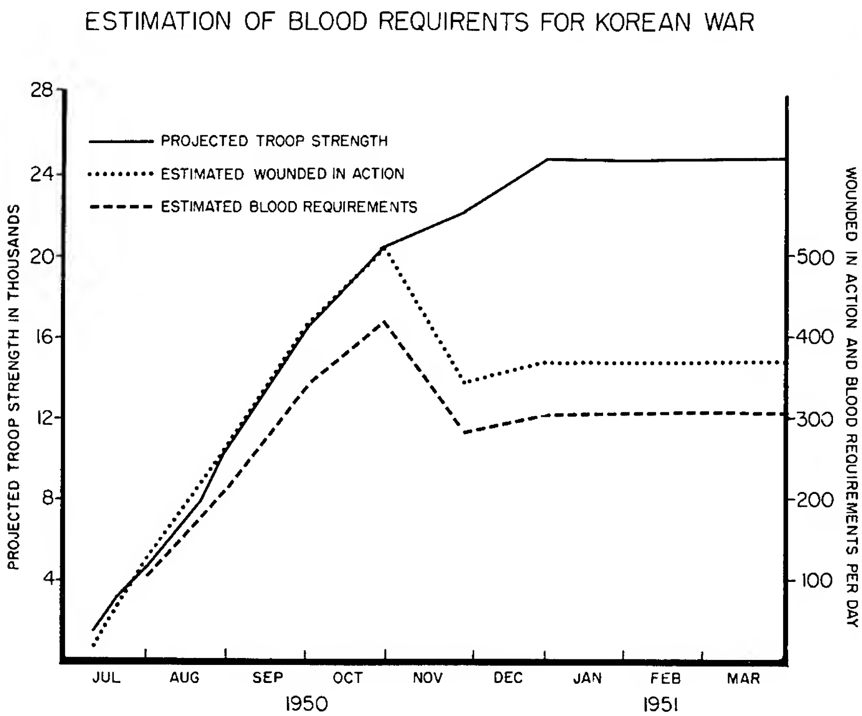


FIGURE 1.

Tokyo plus increased local collections. The increase in shipments from the United States could always be expected 48 hours later.

As regards factors concerned with blood related to casualty rates, there occurred a gradual increase in this ratio throughout the first 18 months of operation (table 1). Exclusive of the early months of the campaign, a sound figure appears to have been 2.4 pints/WIA, three-fourths of this amount having been supplied to the combat zone, the remaining one-fourth to hospitals in what could be considered the communications zone (Japan).

Supply Shortages Affecting the Blood Program. In any sudden and unexpected conversion of an occupation force to full-scale combat, certain supply shortages are to be expected. Constant readiness, careful planning and relatively massive stockpiling must be resorted to in order to avoid this. Critical shortages which affected the local blood program were those of disposable transfusion sets, vacuum bottles for blood collection, and pyrogen-free water.

The limited number of disposable recipient sets were reserved for use in field units in Korea. As a result it was possible to see a direct relationship between use of disposable sets and relative freedom from pyrogenic reactions.

Table 1. Relation of Blood Supply to Wounded in Action in Korean War

Month	Units of blood supplied	Wounded in action	Units per WIA
July 1950	1, 036	1, 872	0. 55
August	2, 923	4, 412	0. 66
September	7, 347	10, 543	0. 69
October	8, 240	2, 678	3. 07
November	5, 893	3, 542	1. 67
December	9, 449	6, 253	1. 52
January 1951	7, 284	2, 789	2. 61
February	11, 724	4, 731	2. 48
March	12, 217	4, 834	2. 53
April	14, 240	4, 853	2. 93
May	15, 906	4, 507	3. 53
June	12, 834	3, 436	3. 74
July	11, 661	1, 628	7. 16
August	9, 776	1, 707	5. 72
September	12, 438	6, 539	1. 90
October	20, 206	9, 968	2. 03
November	14, 999	2, 647	5. 67
December	12, 335	1, 147	10. 75
	190, 508	78, 086	2. 04

This necessary reuse of transfusion apparatus accelerated the developing shortage of pyrogen-free water. Hospitals in Japan were forced to modify standard procedures (*5*) using triple-distilled water only as a final rinse in preparing transfusion equipment. The requirements of the Blood Bank for sufficient pyrogen-free water to permit reprocessing of donor sets were met only by continuous 24-hour operation of an improvised triple-distillation system (*6*), furnishing over 1,000 liters of a product meeting USP specifications (*7*).

As with distilled water, blood donor bottles were too space-consuming to be supplied from the United States by airlift during this early critical period. Fortunately certain Federal Security Specifications were furnished by the Preventive Medicine Consultant. Using these as a guide, close technical supervision and careful laboratory testing allowed local procurement from Japanese manufacturers of acceptable blood-collecting bottles and later disposable donor and recipient sets.

Throughout the early period of the war, the only blood substitute available was dried plasma. In September 1950 even this item became critical when the theater was notified to suspend from issue the available stocks from two major biologic producers. At the same time information was received that plasma-processing capacity in the

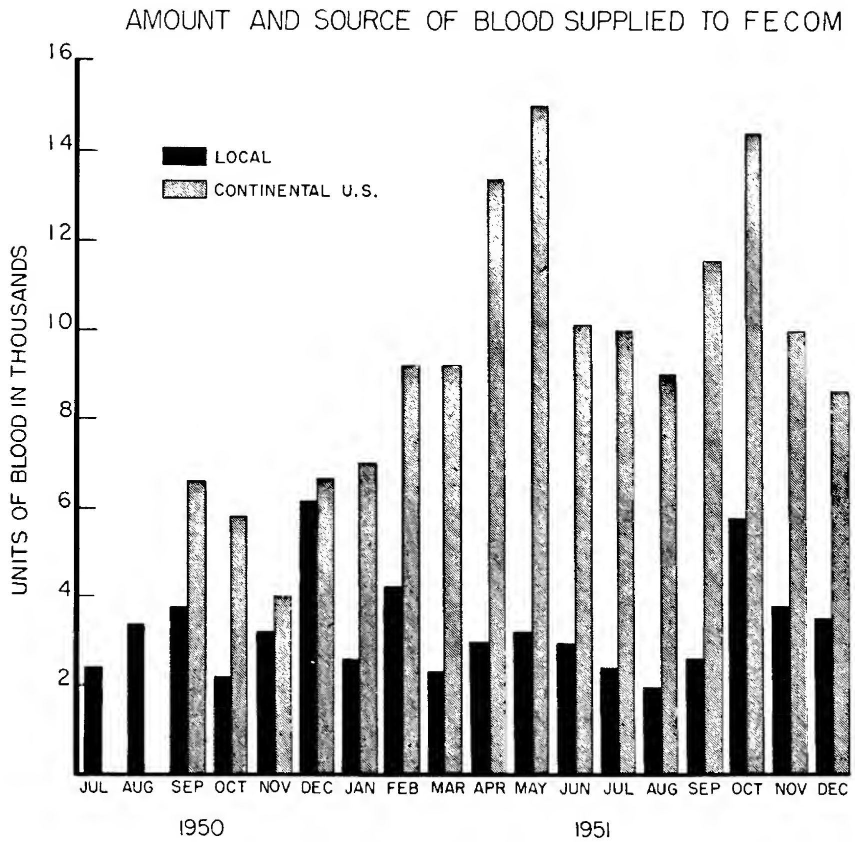


Figure 2.

United States would be inadequate to meet theater requirements for at least 2 months. Hospitals in Japan and Korea were advised to use blood or other substitute in lieu of plasma wherever feasible. This allowed preservation of precious plasma stores for use by division medical units, but undoubtedly was a factor in stimulating greater readiness to use whole blood for resuscitation.

Utilization of Blood. As has been mentioned above, supervision and advice in the use of blood and blood substitutes were lacking. This may account for the unbelievably small amounts of plasma and albumin generally used by medical installations receiving blood. Another possible example of the desirability of closer supervision of the program became apparent in the disappearance in 1951 of a reasonable relationship between blood requisitions and numbers of casualties. The answer was found related to the psychology of preparedness. The soldier who has used his tenth grenade on a combat patrol will not willingly carry a lesser number on his next foray. Similarly, the

hospital commander who has seen 100 pints of blood consumed in a single influx of battle casualties will not decrease his high level of blood on hand until assured active combat has definitely subsided and will not suddenly reappear. Likewise at a theater level there is always realization that excess amounts of blood are undesirable, but inadequate amounts are disastrous.

It is felt only proper to state that a survey conducted in the closing months of 1951 showed that in the first 18 months of the Korean War only two-thirds of blood supplied was actually used in our hospitals in both Japan and Korea.

These facts naturally lead to the problem of disposal of outdated blood. Proposals which were considered were: (a) an additional laboratory unit for a fractionation program, (b) development of Japanese facilities for local fractionation on a contract basis, and (c) return of outdated blood to the Zone of Interior for fractionation. Each of these proposals was carefully evaluated before rejection. Of necessity, and realizing the danger of adverse publicity, circumspect methods of destruction were utilized. Coincidentally a cautious education of the unduly curious was begun. Later, all blood which had passed the 21-day expiration date was turned over to Korean medical authorities who maintained it was quite satisfactory for use. This is not particularly suggested as a pattern for the future, however.

Summary

1. A brief historical account is given of the development of a blood program for a combat theater of limited size.

2. A method is described for planning blood requirements, but it should be remembered that the factors derived may not pertain to other situations.

3. It is suggested that the amount of blood used is possibly more than necessary or available in a military situation of larger scope.

4. The need is stated for a full-time director of a theater blood program who also could serve as an active consultant on the use of blood and blood substitutes.

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STUDIES OF BLOOD VOLUME AND TRANSFUSION THERAPY IN THE KOREAN BATTLE CASUALTY*

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During the years 1952–53 in the Korean War, there was a trend toward giving increasingly large amounts of blood throughout resuscitation. It was not unusual to administer to the critically injured soldier 15 to 30 pints of blood on the day of injury. Much of the blood was given after the control of obvious hemorrhage. The desirability of this practice was often questioned, but was based on the belief that adequate resuscitation (i. e., stabilization of blood pressure and pulse rate at relatively normal levels, subsidence of clinical symptoms and signs of shock) was principally a function of restoration of blood volume. Likewise, during and after surgery, maintenance of blood volume seemed to be the most critical factor in the recovery or death of the wounded patient. The present studies of blood volume in battle casualties were therefore undertaken in an effort to evaluate these clinical impressions by more objective, quantitative methods, particularly with reference to the desirability and necessity for massive transfusions. All blood used in the Korean theater was either type O, banked blood or, rarely, fresh compatible blood.

Several previous studies relative to blood volume following wounding have been carried out (*1*, *7*, *10*). In general, these investigations have stressed primarily the clinical status of the patient as correlated with his blood volume at the time he entered the hospital. For several reasons, we decided to place our emphasis principally on blood volume in the postoperative rather than the *resuscitative phase* of the patient's course. (1) It was felt that more could be learned about the adequacy of transfusion and its effect in maintaining blood volume through resuscitation and surgery. In particular, determinations at this time would provide quantitative answers as to the necessity for large transfusions. (2) In most instances adequate hemostasis was achieved at this time allowing for adequate mixing of the labeled

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cells or dye without significant loss during mixing. (3) Likewise, the rapid administration of blood or colloids was not necessary here, so that mixing phenomena of labeled cells and dye could be observed without being confounded by concomitant mixing of other fluids rapidly infused for resuscitation.

Those patients, therefore, whose blood volumes were determined with labeled red cells were studied during the first 12 to 48 hours after surgery. Where the dye T–1824 was used it was often necessary to wait until the day following surgery to avoid interfering effects due to elevated plasma hemoglobin.

Methods

Labeled Red Cell Method

Labeling of red cells was carried out using radioactive chromium as the tagging material. $Chromium^{51}$ was used in preference to p^{32} because of the more lasting incorporation of Cr^{51} in the red cells as compared to p^{32}. Since with the method used negligible escape of Cr^{51} from the red cells occurs within the first 24 hours, prolonged study of mixing could be carried out and serial volumes determined without the necessity of relabeling new cells. The following is the method used for labeling the red cells and calculating the blood volume.

1. *Preparation of labeled red blood cells.*
   - (a) Ten cc. of sterile, physiologic saline and 150 to 200 microcuries of radioactive chromium are placed in a sterile, glass-stoppered flask.
   - (b) Fifteen cc. of fresh heparinized "O" blood* is added to the centrifuge flask.
   - (c) The flask is placed in an incubator at 38° C. and allowed to react for 1 hour, mixing gently every 10 minutes.
   - (d) The red cells are washed 3 times with sterile saline.
   - (e) The washed red cells are suspended in 2 volumes of saline and stored at refrigerator temperature until ready for use.
   - (f) If the cells are to be stored for several hours before use, they are resuspended in 2 volumes of plasma obtained from bank blood.
2. *Red blood cell volume determination.*
   - (a) The labeled red cell suspension is thoroughly mixed and aspirated into a syringe of suitable volume.
   - (b) At least 2.5 cc. of labeled blood from the syringe is placed into a tared volumetric flask as a standard, weighed, and made to volume with distilled water.

*Fresh labeled "O" cells were used in preference to the patient's cells so that a source of labeled cells would be readily available on short notice whenever needed.

(c) The syringe containing the material to be injected is weighed together with the needle to be used for injection.

(d) The remaining labeled blood is injected intravenously and the syringe and needle are immediately weighed without rinsing.

(e) Blood samples are collected 20 and 40 minutes after injection and as indicated thereafter until mixing is complete. In most cases, multiple samples were taken until the last 2 aliquots differed by less than 5 percent.

(f) The hematocrit of each sample is carefully determined. At least 3 hematocrits were obtained on each patient.

(g) Exactly 5 cc. of each whole blood sample is pipetted into a counting test tube. Likewise, duplicate 5 cc. samples of standard are pipetted into counting tubes.

(h) All standards and samples are counted in a well-type scintillation counter.*

3. *Computations.*

The blood volume is calculated using the standard dilution formula

$$C_1V_1 = C_2V_2 \text{ or } V_2 = \frac{C_1V_1}{C_2}$$

where C_1 = cpm/cc. of injected material
V_1 = volume of injected material
C_2 = cpm/cc. of patient's blood
V_2 = volume of patient's blood.

In this instance:

$$C_1 = \frac{\text{cpm/cc. of diluted standard x volume to which standard was diluted}}{\text{Weight of labeled blood used as standard}}$$

V_1 = Weight of syringe and needle before injections minus weight after injection.
C_2 = cpm/cc. of patient's blood after adequate time for mixing of labeled cells has been allowed.
V_2 = Resultant calculated blood volume.
TRCV = Hematocrit x total blood volume.
Plasma volume = total blood volume minus TRCV.

Dye Method

When the dye T–1824 was used for plasma and blood volume determination, the technic of Gregerson, *et al.*, (*8*, *9*) was utilized wherein three plasma samples were taken at 13 to 15, 30 and 45 to 60-minute intervals. The dye concentration of each sample was measured and plotted against time. The curve so obtained was extrapolated linearly back to zero time to correct for dye loss during the mixing period. This value at zero time gave the theoretical concentration of dye that would have occurred in the plasma if uniform mixing had been effected at the instant of injection and none of the dye had been

*Standard scintillation counting technics were used.

excreted. Where abnormal plasma hemoglobin levels or an interfering cloudiness were suspected the samples were discarded. Each reported determination was made on the basis of three valid samples with the exception of those so indicated where extrapolation was on the basis of only two. When only one plasma level was obtained or when a linear plot did not result the observation was discarded. The total blood volume was calculated from the plasma volume and the hematocrit value. Where simultaneous blood volumes were determined by using labeled cells and dye, the two were administered separately via different veins to avoid error through loss during changing of syringes.

In calculating the total blood volume from the plasma volume or red cell volume, no correction factors were used to effect the possible error introduced by differences between venous and total body hematocrit. The estimated normal blood volume used for the dye method was 8 percent of body weight, and for the labeled red cell method 70 cc./kilo body weight (*2*).

Control

1. *Radio Chromium, Red Cell Tag*
   (a) Fresh red cells labeled with Cr^{51} and resuspended in 2 volumes of saline showed a transfer of 1.5 percent of the total radioactivity to the suspending medium in 36 hours. When bank blood plasma was used for resuspension less than 0.5 percent of the total radioactivity appeared in the supernatant fluid.
   (b) Counting of multiple samples of standard Cr^{51} solution, a total of 10,000 counts for each sample gave a standard deviation of 1.6 percent.
   (c) The red cell volumes of several normal individuals were determined as indicated in table 6. Three duplicate determinations done several days apart gave volumes differing by 0.5, 1.7 and 4.2 percent of the total. In each instance the second determination was made with cells that had been stored 6 hours after labeling with Cr^{51}.
2. *Evans Blue Dye*
   Nine patients who received no transfusions had multiple plasma volume determinations during their postoperative course. Using these volumes and the hematocrit to compute the red blood cell volume it was found that the results were constant within an estimated variation of S. D. $= \pm 5$ percent.

Results

The results are tabulated in tables 1 through 3.

Careful evaluation of mixing was carried out during the first 60 to 90 minutes in all patients to make sure that the volume was calculated from completely mixed samples. Samples were taken until successive counts differed by less than 5 percent. Furthermore, because it was suspected that relatively sequestered areas of blood might exist in some

of these patients (*5*, *13*, *15*), later samples were taken in nine individuals. It was reasoned that if such areas existed and they were not completely sequestered, late samples might have mixed into larger volumes which were not apparent in earlier samples. The results of these studies are seen in table 2. It can be seen that even though the early samples had reached a plateau and agreed with one another within less than 5 percent, later samples taken at varying intervals revealed slightly greater apparent volumes in most instances. In all but Case No. 1, the later samples also fell within less than 5 percent of one another. The interpretation of these findings is open to some question owing to the possibility of selective destruction of labeled cells. Two patients were given hexamethonium after the early mixing of labeled cells was complete. It was felt that if slowly mixing, stagnant areas of blood existed, the opening of arterioles and increased flow caused by hexamethonium might improve the circulation through such sites with more complete mixing of labeled cells therein. This process, if it occurred, would increase the measured blood volume. In the two instances, sufficient drug was administered to lower the systolic pressure from the range of 120 to 130 down to 90 to 100. Neither individual showed any increase in volume at intervals of 30 to 60 minutes thereafter.

The postoperative blood volume measurements revealed one outstanding result, namely, that large transfusions were a definite necessity in many of these patients and very rarely resulted in overtransfusion. In fact, regardless of the amount of blood received, the vast majority of patients emerged from surgery with some deficit of total blood volume. Of the 25 patients studied with dye none revealed an initial postoperative blood volume greater than normal. In only 3 patients out of 28 studied with Cr^{51} labeled red cells was overtransfusion present, and in none of these was there any evidence of cardiorespiratory difficulty. This was probably due to the fact that the degree of overtransfusion was minimal. Two of the three overtransfused patients were followed with successive blood volume measurements. In one instance, the red cell volume returned to normal in 9 days and in the other in 7 days. The latter's course, however, was complicated by jaundice and purpura apparently due to thrombocytopenia. Of the three overtransfused patients, one had an abdominal wound and the other two had thoraco-abdominal wounds. They received 7,000, 7,000 and 1,500 cc. of blood respectively.

Clinical State

In general, varying degrees of hypovolemia were tolerated very well by the group during this postoperative period. Fourteen or 58 percent of the weighed patients studied with labeled cells showed

deficiencies of 15 percent or more of the average normal for their weight. We would class this group as definitely undertransfused. The average deficiency for these patients was 32 percent. However, of the 14 patients only 3 were in shock, these patients showing deficiencies of 38, 43 and 52 percent, respectively. The others were doing well postoperatively with no clinical evidence of shock. The average amount of blood which had been received prior to the blood volume determination in this hypovolemic group was 6,740 cc. This figure is in contrast to the group whose deficit was less than 15 percent. Their average replacement was 3,187 cc. or less than half that of the hypovolemic patients. The results were even more striking in the patients studied with dye. Fourteen of the 18 patients whose weights were known and whose normal blood volume could therefore be calculated revealed a deficit of greater than 15 percent. Their average deficit was 31 percent. All these patients were doing well postoperatively with no clinical evidence of shock. Their blood requirement pattern was similar to that of those studied with labeled cells, the group with greater than 15 percent deficit having received 7,785 cc. and the group with less than 15 percent deficit receiving 4,160 cc. Thus those individuals who had required the most blood remained the most hypovolemic following surgery. It was in this group that the most massive transfusions were required.

In only one patient did shock exist in the presence of a normal blood volume. This patient had received severe head injuries, with shell and bone fragments in the brain substance. In addition, there were severe facial injuries and a compound comminuted fracture of the left humerus. This patient had received 4,500 cc. of blood prior to the blood volume determination, which measured 96 percent of normal for his weight. The volume was done 3 hours before his death at which time his pulse was 140 to 160, respiration 40 to 50, B. P. 120/100 dropping to 90/70 during the succeeding hours. He died in severe pulmonary edema. The severe brain injury was undoubtedly of paramount importance here and may well explain the shock picture in the presence of a normal blood volume.

When the patients are placed in categories dependent upon the location of their wounds, several trends relative to blood volume and blood requirements come to light. In view of the relatively small numbers of patients, these trends must be considered tentative. They seem to be dependent primarily on one fundamental factor, the presence or absence of large areas of muscle injury. In the extremity wounds where a large amount of muscle injury was almost invariably present, large amounts of blood were necessary during resuscitation and surgery. Yet when the blood volume was determined postoperatively by either method, all members of the group fell in the hypovolemic class

with deficits in volume of 15 percent or more and an average hematocrit of 36.5.

On the other hand, those who had abdominal wounds, though they had received a similar amount of blood as compared to those with extremity wounds, revealed postoperative blood volumes more closely approximating normal and an average hematocrit of 45.8. The excess loss of blood from wound of muscle is easily understood when one considers the local pathology involved in wounds caused by implements of war. Although there may be only a small wound of entrance, there is a large amount of destruction of the underlying muscle. This is particularly true in high-velocity missile wounds. Bleeding from the large mass of damaged muscle continues from the time of injury until operation. During this time, the blood loss is greater than the observer generally realizes. The importance of other factors, such as hemolysis and trapping of blood, as added mechanisms for the causation of these low blood volumes is not fully known at the present time.

Relation of Hematocrit

Table 3 illustrates 10 patients with extremity wounds on whom serial postoperative hematocrits were done. They show a consistent fall in hematocrit. One factor which may contribute in part to this effect is the rise in plasma volume observed in many hypovolemic convalescent patients. A rising plasma volume and falling hematocrit were noted in the absence of any significant change in the total red cell volume indicating a dilution effect as being at least partially responsible for the falling hematocrit.

As has been previously reported, hemoconcentration characteristically follows severe intra-abdominal injuries (*1*). This is probably due to the loss of plasma in excess of red cells into the bowel wall, mesentery and peritoneal cavity. Serial postoperative hematocrits in patients with abdominal injuries are compared with the postoperative changes following wounds of the extremities in table 3. Because hemoconcentration and plasma loss were so frequently quite marked, surgeons often administered dextran as an adjunct to blood transfusion therapy during and after repair of major intra-abdominal injuries. This was true during much of the time when these data were collected.

Comparative Blood Volumes

In 15 patients, simultaneous blood volume determinations were carried out using labeled red cells and T–1824. The results are recorded in table 4. In general the methods agreed fairly well, the average difference being 16.3 percent and falling in the range of difference found by previous investigators in normal individuals. In three patients, however, the discrepancy was considerably larger (26 to 39 percent), the dye volume being larger in all instances. All of

these individuals had severe abdominal wounds; two of the three had lacerations involving the liver. This would suggest that the same factor causing hemoconcentration in such patients allows for leakage of dye out of the vascular system with resultant falsely high plasma and blood volume determinations. Peters (*12*) has commented previously on the loss of the dye, T–1824, from the blood stream particularly in the liver vasculature. The involvement of the liver in two of these three cases is therefore of added interest and significance. These data suggest that under certain circumstances the dye method may not be a reliable one.

Discussion

The impression was originally gained by those in the North African-Mediterranean Theater (*1*) that blood loss rather than any other factor was responsible for shock in the wounded patient. Their findings indicated that the presence or absence of shock as well as its degree upon admission to the hospital was directly correlated with the deficiency in blood volume present at that time. The present studies lend support to those findings and extend the concept to the surgical and postoperative period where it is seen that tremendous amounts of blood are often necessary to maintain the blood volume close to normal range. Of the 52 patients studied, 31 or 59.6 percent required over 10 pints of blood. In other words, over half of the patients studied required complete replacement of their blood volume. Of these 31 patients, 9 required 20 pints or roughly twice their blood volume. This group emphasized well the real necessity in some patients for massive transfusions. The average deficiency of blood volume in these 31 individuals after receiving such massive transfusions was still 25.2 percent.

In addition to the problem of how large a circulating blood volume was necessary for these patients was that of how effectively the blood transfused had increased that volume. Possibly present in almost every patient observed but becoming more apparent with the larger volumes of transfusion, was an apparent discrepancy between the amount of blood transfused and that actually measured after operation. This volume deficit appears to consist of both plasma and red blood cells. As examples the data of table 5 were extracted from table 1 and arbitrary estimates of admission blood volume made. Most of these patients were chosen as examples because the volumes involved were large enough to make errors in estimation of initial volume relatively insignificant. They demonstrate an average deficit of 5,373 cc. with a range from 1,600 to 7,900 cc. Likewise 10 patients requiring postoperative transfusions were studied with one or more determinations of their plasma volume with Evans Blue for up to 7 days after wounding. The results are tabulated in table 7. When a transfusion intervened between two determinations, the change in

circulatory red cells measured was significantly less than that expected in 6 of 12 instances. None of these patients showed clinical reason to suspect red cell loss.

It was because of these consistently low blood volumes after large transfusion and the discrepancy between the volume of blood infused and that measured thereafter that such concern was shown over the possibility of incomplete mixing of labeled cells in relatively sequestered areas of blood volume. If large amounts of blood were pooled in areas relatively inaccessible to mixing, falsely low total blood volumes would be the result. Although the blood volumes calculated from late samples were slightly greater than those calculated from early ones, in no instance did they result in a blood volume of 5,000 cc. or over. One of the nine patients (table 2) showed an increase of 1,565 cc. in blood volume as calculated from the late samples. He had previously been resuscitated with only 2,500 cc. of blood. Seven of the remaining eight patients (one patient—no data) received 10,500, 10,000, 8,500, 7,500, 7,000, 3,500 and 3,500 cc. respectively, and the blood volume increase when calculated from the late samples as compared with the early samples was 600 cc. or less in every instance.

Likewise in the two patients given hexamethonium no increase in blood volume occurred concomitant with the fall in blood pressure. Furthermore, in those patients who had received massive transfusion and survived, none developed clinical or laboratory evidence of overtransfusion during their postoperative course. If such a pooling mechanism as has been postulated existed early, one would expect a reversal of this process during clinical recovery with mobilization of substantial amounts of trapped blood and some resultant evidence of overtransfusion. In no instance did such occur. Although these data are not sufficient for positive conclusions, they do not support the concept that a significant amount of pooling existed in these patients receiving massive transfusions.

Further answers to this question might be obtained by two approaches. (1) Weigh the patient on an accurate scale when he enters the hospital. When resusitation and surgery are completed, weigh again and determine the blood volume. Where such large volumes of infused blood are involved, one should see significant gains in weight if most of the blood has been retained; little or no change if it is being lost externally as fast as it is being infused. Correlating the postoperative blood volume with change in weight would thus help clarify the question of loss versus pooling. Obviously if most of the bleeding was into the tissues little would be learned by this procedure. (2) Determine the blood volume postoperatively with chromium-labeled cells. Determine the hemoglobin to Cr^{51} ratio in blood and in tissue biopsies such as muscle. If large amounts of blood are sequestered in the tissues and inaccessible to the labeled cells, the hemo-

globin to chromium ratio will be increased considerably in the tissues.

The quality of bank blood used for transfusion was investigated (*3*), and so far as indicated by the indices used (plasma Hgb, plasma potassium, and osmetic fragility) this blood was comparable to that available in the United States.

Investigation by means of the Ashby count, was reported previously (*3*), indicates that in a small portion of A, B and AB receipts receiving large amounts of O blood there will be a destruction of the patient's own cells extending over several days but this is relatively infrequent and usually involves volume changes much smaller than those reported here.

The relative importance of hemolysis of recipient and donor cells as a contributing cause for the large requirement of blood replacement in these patients is not fully known at the present time. These patients do not show overt clinical manifestations of rapid blood destruction such as chills, fever and jaundice. Moreover, the average plasma hemoglobin done immediately after surgery in 22 patients who had received an average of 12 pints of blood each day was only 18 mg. per 100 cc. (*3*), (normal 5 mg. per 100 cc). Since the intravenous infusion of 10 to 16 gm. of Hg. (equivalent to hemolysis of 60 to 100 cc. of blood) in normal individuals will induce plasma Hg. levels of greater than 300 mg./100 cc. (*6*, *11*), the levels found in these postoperative patients would be indicative of minimal intravascular hemolysis. The rate of plasma Hg. clearance is of course a factor here. The most rapid clearance rate found in the group studied was 5 mg. per 100 cc. per hour which would be insufficient to lower a significantly high concentration of Hg. to the levels found even over a period of many hours.

Likewise the observed bilirubin levels in a similar group of patients (*14*) would correspond to a relatively small degree of blood destruction. The rate of plasma clearance, principally by the liver, is again a critical factor here and the necessary data for such evaluation in these patients are not at hand. The infusion of 16.4 gm. of Hg. (*6*) (equivalent to hemolysis of approximately 100 cc. blood) in a normal individual resulted in a plasma bilirubin concentration of 1.4 mg. for 100 cc. 10 hours later, with a gradual fall thereafter and remaining greater than the pre-injection level 24 hours later. Clearance of bilirubin in the wounded patient, where impaired hepatic function has been shown by others (*1*, *14*) would be expected to be slower than in normals. Therefore the 6-hour postoperative average level of 2.5 mg. per 100 cc., which is the highest level reached in any of the preoperative and postoperative specimens, would imply relatively small amounts of hemolysis.

The postoperative hematocrit afforded a relatively poor index to the requirements for transfusion. Because of rapid changes in

plasma volume which take place independently from changes in red cell volume after extensive blood loss, the hematocrit gives little information about the actual red cell volume at any given time. By the same token any conclusions concerning the status of total blood volume drawn from hematocrit data alone are likely to be in error.

Conclusions

Blood volume determinations have been carried out postoperatively in 52 wounded patients. These patients required large amounts of blood to maintain them through the phases of resuscitation and surgery. Generally patients with extremity wounds, where large amounts of muscle destruction had taken place, required the largest amounts of blood and still remained the most hypovolemic following surgery. However, no matter where the injury was located, if considerable areas of muscle were involved, large amounts of blood were usually required.

Overtransfusion occurred in only three instances and in no case was it of sufficient degree to cause cardiorespiratory symptoms. The error in most cases was undertransfusion rather than overtransfusion.

Hematocrit determinations in the postoperative period are not a reliable index to the requirement for blood.

Where simultaneous blood volumes were determined with labeled cells and dye, the difference between the two was 16 percent, the dye volume being greater in all but four instances. However, in severe abdominal wounds, especially with liver involvement, the discrepancy was much larger. Here the dye volumes were greater by 26.8, 33 and 39 percent. This probably represents increased capillary permeability and gross vascular damage in the involved area with resultant leakage of dye.

The discrepancies between the large amounts of blood given and the small blood volumes determined thereafter are explainable on three possible bases: (1) Trapping of large amounts of blood in a sequestered state which mixes slowly or not at all; (2) hemolysis of large amounts of donor and/or recipient erythrocytes; (3) continued loss of blood either externally or into the tissues during the preoperative, operative and postoperative periods. The latter is believed, at the present time, to be the most important of these factors.

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Table 1A. Blood Volume Determined With Radioactive Chromium

Case No.	Weight Kg.	Hemat.	TRCV		Plasma volume		Blood volume		Blood received (cc.)	Percent normal	Wounds
			cc./K	Total	cc./K	Total	cc./K	Total			
						Abdominal wounds					
1	------	46	------	1, 912	------	2, 436	------	4, 346	2, 000	--------	Carbine wounds—lac. of spleen and stomach.
2	74. 6	38	17. 4	1, 298	28. 6	2, 118	46. 0	3, 416	6, 000	65	Carbine wounds entering over left inguinal ligament, perf. bladder and leaving via left buttock. Retroperitoneal muscle damage.
3	72. 8	46	26. 4	1, 990	34. 8	2, 533	60. 2	4, 523	3, 000	89	Carbine wounds entering left flank. 5 perfs. of jejunum, 2 perfs. descending colon.
4	58. 6	36. 5	19. 6	1, 148	36. 4	2, 132	56. 0	3, 280	10, 500	80	Mortar—cpd. fracture rt. ilium with perf. wound of flank, buttock and rt. retroperitoneal area. Tremendous muscle destr. and hemorrhage.
	58. 6	38. 5	23. 8	1, 390	36. 2	2, 221	60. 0	3, 611	11, 500	86	1 day later.
5	------	48. 5	------	1, 780	------	2, 052	------	3, 832	6, 000	--------	Mortar—extensive lac. rt. lobe of liver, perf. of ascending colon, duodenum, ileum; lac. 2 lumbar veins; perf. of diaphragm.
6	*66	42. 5	16. 4	1, 082	23. 6	1, 558	40. 0	2, 640	500	57	Mortar—6 perfs. of ileum, fracture mid-left ilium, muscle injury to gluteus, iliacus and psoas; 2,000 cc. blood in peritoneal cavity.
	66	43. 5	27. 5	1, 820	38. 5	2, 540	66. 0	4, 360	6, 000	94	1 day later—postoperatively.

7	63. 8	68	47. 1	3, 002	25. 5	1, 628	72. 6	4, 630	7, 000	104	Mortar—extensive lac. small bowel and colon, requiring resection of 2 segments. Renal insufficiency, purpura, death.
	63. 8	68	48. 7	3, 105	26. 0	1, 655	74. 5	4, 760	7, 000	107	1 day later.
	63. 8	48	29. 1	1, 855	34. 1	2, 175	63. 2	4, 030	7, 000	91	1 week later.
8	56. 4	48	28. 6	1, 615	33. 5	1, 885	62. 1	3, 500	2, 000	89	Mortar penetrating pelvis dorsally—perf. of ileum in 4 places, perf. of rectosigmoid.
$\overline{M}$	65. 4	45. 8	27. 1	1, 772	33. 3	2, 171	60. 4	3, 943	5, 300	86. 7	
						Extremity Wounds					
9	------	41	------	1, 625	------	2, 339	------	3, 964	------	------	Mortar—perf. rt. and left thighs, left elbow, CCF rt. patella with multiple bone fragments in knee.
10	60. 0	31. 0	16. 0	962	37. 4	2, 246	53. 4	3, 208	2, 500	76	Mortar—rt. inguinal region and rt. buttock with a large amount of muscle damage.
11	95. 5	43. 5	27. 1	2, 580	33. 0	3, 128	60. 1	5, 708	6, 500	85	Mult. pen. wds. both thighs. Cpd. comm. fracture of tibia and fibula bilaterally. Traumatic amput. of rt. hand.
12	72. 6	40. 0	19. 4	1, 410	31. 0	2, 250	50. 5	3, 660	3, 500	72	Mortar—CCF upper ⅓ rt. tibia. Large perf. wds. of rt. and left thighs.
13	72. 8	32. 0	13. 9	1, 010	31. 4	2, 290	45. 3	3, 300	4, 250	65	CCF of left tibia and fibula with extensive soft tissue damage.
14	61. 3	33. 0	16. 0	982	34. 6	2, 118	50. 6	3, 100	4, 500	73	CCF of rt. tibia and fibula. Perf. wound of thigh.

Table 1A. Blood Volume Determined With Radioactive Chromium—Continued

Case No.	Weight Kg.	Hemat.	TRCV		Plasma volume		Blood volume		Blood received (cc.)	Percent normal	Wounds
			cc./K	Total	cc./K	Total	cc./K	Total			
Extremity Wounds—Continued											
15	76. 5	32. 0	16. 8	1, 285	37. 8	2, 895	54. 6	4, 180	9, 500	78	Traumatic severance of femoral artery and vein in mid-thigh (rt.). Extensive muscle damage medial rt. thigh. Subtotal severance sciatic nerve.
M̄	73. 1	36. 0	18. 2	1, 408	34. 2	2, 466	52. 4	3, 874	5, 125	75	
16	72. 8	51	33. 7	2, 452	32. 4	2, 356	66. 1	4, 808	1, 500	94	Mortar wounds—both legs. Small intrapelvic fragments of level of S_1. 5 perfs. of ileum.
*17	------	36. 0	------	1, 956	------	1, 814	------	2, 770	3, 500	--------	Multiple mortar wounds both hands, arms and thighs. 30 perfs. of small bowel. Lac. left common iliac vein.
18	71. 0	43. 0	23. 5	1, 675	33. 5	2, 380	57. 0	4, 055	7, 500	82	Artillery wounds—Traumatic amput. both arms. Mult. pen. wds. of liver. Multiple perfs. of small bowel.
*19	59. 6	40. 0	16. 7	992	26. 6	1, 589	43. 3	2, 581	7, 000	62	Mine injury—CCF left tibia and fibula. CCF rt. tibia and fibula lower third with traumatic amput. rt. foot; large perineal wound with retroperitoneal hematome.
M̄	67. 8	42. 5	24. 6	1, 769	30. 8	2, 034	55. 5	3, 553	4, 875	79	

Thoraco-Abdominal Wounds

20	67. 4	43. 0	26. 2	1, 760	37. 2	2, 513	63. 4	4, 273	--------	91	Mortar wds. thru 10 I. S., midaxillary line of left chest, perforating diaphragm and left lobe of liver. Fragment embedded in serosa hepatic flexure.
21	54. 0	57. 0	45. 5	2, 480	37. 9	2, 055	83. 4	4, 535	7, 000	120	Mortar wds.—Pen. avulsive thoraco-abdominal wound, left with fracture of ribs 9 and 10, hemothorax; laceration of diaphragm, spleen, and stomach.
	54. 0	50. 7	42. 9	2, 320	45. 7	2, 470	88. 6	4, 730	7, 000	127	3 days later.
	54. 0	41. 0	28. 1	1, 518	46. 7	2, 525	74. 8	4, 042	7, 000	107	9 days later.
22	52. 2	51. 0	41. 6	2, 170	43. 3	2, 260	84. 9	4, 430	1, 500	121	Mortar wds.—Fract. ribs 11 and 12, lac. of diaphragm ruptured spleen, hemopneumothorax.
23	57	35	23. 5	1, 340	43. 7	2, 490	67. 2	3, 830	2, 500	96	Mortar wds.—SFW pen. rt. shoulder and entering chest. Hemothorax. Pen. wound rt. lobe of liver.
	57	37	28. 4	1, 617	48. 3	2, 753	76. 8	4, 370	3, 100	110	2 hours later—after 600 blood with Ht. 46.
$\overline{M}$	57. 6	46. 5	34. 2	1, 937	40. 5	2, 329	74. 7	4, 267	2, 500	107	--------------------------------

Chest-Extremity Wounds

*24	82. 0	28	9. 0	736	24. 4	2, 004	33. 4	2, 740	10, 000	48	Mortar wounds—Mult. pen. wds. rt. chest, hemothorax. Mult. fragments in both thighs. Fractures of left radius, upper third left tibia and 5 metacarpals left hand.

Table 1A. Blood Volume Determined With Radioactive Chromium—Continued

Case No.	Weight Kg.	Hemat.	TRCV		Plasma volume		Blood volume		Blood received (cc.)	Percent normal	Wounds
			cc./K	Total	cc./K	Total	cc./K	Total			
					Chest-Extremity Wounds—Continued						
25	68. 0	42	28. 2	1, 915	39. 8	2, 835	68. 0	4, 750	10, 000	100	Mortar wds.—Fracture of pelvis, rt. humerus compound. comm. Hemopneumothorax.
26	79. 5	43	23. 8	1, 890	33. 7	2, 290	53. 0	3, 600	7, 500	65	Mortar wds.—Perf. SFW neck and chest. Massive hemopneumothorax. Extensive lac. upper lobe left lung.
$\overline{M}$	76. 5	37. 6	20. 3	1, 513	32. 6	2, 376	51. 4	3, 696	9, 166	71	
					Miscellaneous Wounds						
*27	50. 0	43. 0	28. 3	1, 445	39. 0	1, 915	67. 3	3, 360	4, 500	96	Mortar wds.—Right temporal wound with intracranial shell fragments and bone fragments. Severe CCF of mandible with extensive hemorrhage. CCF left humerus. SFW left knee.
28	75. 0	40. 0	16. 4	1, 230	26. 4	1, 980	42. 8	3, 210	8, 500	61	Artillery wd.—CCF left temporoparietal area of skull with depression. CCF rt. femur. Compound fracture rt. radius, and ulna.
$\overline{M}$	62. 5	41. 5	22. 3	1, 337	65. 4	1, 947	55. 0	3, 285	6, 500	79	

*In shock.

Note. 1. The preoperative volumes of case No. 6 are not included in the mean for the group.
2. Only the initital postoperative volume of case No. 7 is included in the mean for the group.

Table 1B. Blood Volume Determined With T–1824

Case No.	Date injured	Weight Kg.	Hemat.	TRCV (cc.)	Plasma volume (cc.)	Blood volume (cc.)	Blood received (cc.)	Percent normal	Date of volume	Estimated normal (cc.)	Wounds
					Abdominal Wounds						
29	9 June	58. 2	47	2, 150	2, 420	4, 520	5, 500	101	10 June	4, 500	SFW—Face, neck, eye, perf. stomach, small bowel, middle colic artery.
			48	2, 050	2, 400	4, 450			16 June		
30	14 July	83. 8	40	1, 670	2, 720	4, 390	6, 500	66	15 July	6, 700	Mortar wds.—Pen. wound of flank, multiple perf. of small bowel and colon, perf. of ureter, retroperit. hematoma.
			39	1, 860	3, 160	5, 020			17 July		
			46	2, 340	2, 910	5, 250	*1, 000		20 July		
31	28 July		46	2, 740	3, 490	6, 230	10, 500		28 July		Carbine wds.—Pref. of duodenum and I. V. C. Post-traum. renal insufficiency.
			47	2, 780	3, 400	6, 180	1, 000		29 July		
32	2 Sept.	77. 6	49	2, 170	2, 450	4, 620	7, 500	75	5 Sept.	6, 200	Machine gun—Perf. of internal iliac, arter., vein and colon.
			41	2, 040	3, 190	5, 232			9 Sept.		
			45. 5				7, 500	80. 6			

Table 1B. Blood Volume Determined With T-1824—Continued

Case No.	Date injured	Weight Kg.	Hemat.	TRCV (cc.)	Plasma volume (cc.)	Blood volume (cc.)	Blood received (cc.)	Percent normal	Date of volume	Estimated normal (cc.)	Wounds
						Extremity Wounds					
33	6 June	------	44	1, 780	2, 260	4, 040	4, 500	------	7 June	------	Perf. fem. art. and vein, pen. wds. both lower extremities, transfns. react. 14 June $\bar{c}$ dev. of oliguric. Blood+.
34	15 June	65. 0	35	1, 230	2, 380	3, 610	7, 000	68	16 June	5, 200	Mortar wds.—Massive muscle wd. of thigh $\bar{c}$ cp'd. commin. fract. of pelvis. Two perf. of fem. and iliac ar. Died 16 June.
35	7 July	61. 2	33	1, 010	2, 190	3, 140	4, 000	64	8 July	4, 900	Mine injury—Came in in shock. Traumatic amp. of left foot, macer. and fractures rt. foot.
	------	------	25	940	2, 980	3, 920	------	------	10 July	------	
36	7 July	77. 6	37	1, 800	3, 200	5, 000	7, 500	81	8 July	6, 200	Mine wd.—Traumatic amp. of rt. foot. Destruction of muscle of calf.
	------	------	33	1, 850	3, 900	5, 750	------	------	10 July	------	
37	18 July	61. 3	36	1, 400	2, 720	4, 120	8, 500	84	18 July	4, 900	Mine injury—Traumatic amp. left foot. Muscle destruction rt. calf.
	------	------	28	1, 360	3, 640	5, 000	------	------	21 July	------	
	------	------	35	1, 650	3, 200	4, 850	*1, 500	------	25 July	------	

38	18 July	------	34	1, 240	2, 630	3, 870	3, 000	--------	19 July	--------	Mine injury—Traumatic amp. both legs at calf.
	---------	------	33	1, 540	3, 260	4, 800	1, 000	--------	21 July	--------	
	---------	------	42	2, 200	3, 300	5, 500	1, 500	--------	25 July	--------	
39	12 Aug.	------	40	1, 930	3, 010	4, 940	8, 000	--------	13 Aug.	--------	Mine injury—In shock on entry. Extens. cp'd commin. fracts. both tibia c̄ traumat. amp. of left leg at calf. Rt. leg at calf incompletely amp. Massive wd. left arm and of muscle and skin of thighs. Gas gangrene. Renal insuff.
40	19 Aug.	70. 0	26	770	2, 380	3, 150	9, 500	56	19 Aug.	3, 600	Artillery wds.—Massive cp'd commin. fract. both femurs and pelvis. Massive muscle destruction.
	---------	------	24	1, 010	3, 200	4, 210	500	--------	20 Aug.	--------	
	---------	------	52	2, 700	2, 700	5, 400	*5, 000	--------	23 Aug.	--------	
41	2 Sept.	77. 6	41	1, 920	3, 100	5, 080	10, 500	82	2 Sept.	6, 200	Mine injury—Traumatic amp. both legs, high thigh.
	---------	------	44	2, 270	3, 140	5, 410	1, 500	--------	6 Sept.	--------	
	---------	------	47	2, 670	3, 260	5, 930	--------	--------	10 Sept.	--------	
42	6 Sept.	77. 6	42	1, 690	2, 570	4, 260	7, 000	69	6 Sept.	6, 200	Mortar wds.—Traumatic amp. left leg (high calf) and rt. foot. Soft tissue wds. rt. leg.
	---------	------	47	1, 600	1, 900	3, 500	--------	--------	7 Sept.	--------	
	---------	------	30	1, 480	3, 060	4, 540	--------	--------	10 Sept.	--------	

Table 1B. Blood Volume Determined With T-1824—Continued

Case No.	Date injured	Weight Kg.	Hemat.	TRCV (cc.)	Plasma volume (cc.)	Blood volume (cc.)	Blood received (cc.)	Percent normal	Date of volume	Estimated normal (cc.)	Wounds
						Extremity Wounds—Continued					
43	20 Sept.	------	38	600	1, 070	1, 870	12, 000	--------	21 Sept.	--------	Mortar wds.—All four extremities amputated. Both legs at calf and both hands.
	---------	------	47	1, 665	1, 880	4, 180	11, 500	--------	22 Sept.	--------	
44	22 Sept.	70. 0	38	1, 360	2, 420	3, 780	6, 000	67	23 Sept.	5, 600	Artillery wds.—Traumatic amp. of rt. leg at knee, comp. commin. fracture left radius and ulna.
	---------	------	37	1, 320	2, 440	3, 720	--------	--------	24 Sept.	--------	
	---------	------	37	--------	--------	--------	7, 290	71. 4	---------	--------	
						Abdominal + Extremity Wounds					
45	4 Aug.	77. 6	42	1, 270	1, 750	3, 020	10, 500	49	4 Aug.	6, 200	Perf. of TVC., small bowel, poplit. artery. In prof. shock.
	---------	------	45	1, 650	2, 010	3, 660	1, 500	--------	7 Aug.	--------	
	---------	------	41	1, 410	2, 170	3, 580	1, 000	--------	12 Aug.	--------	

Thoraco + Abdominal Wounds

46	--------	------	63	2, 500	1, 630	4, 130	6, 000	--------	4 Sept.	--------	Carbine wds.—Perf. of lung, liver, stomach and diaphragm, and colon.
	--------	------	51	2, 760	2, 870	5, 630	--------	--------	6 Sept.	--------	
	--------	------	47	2, 870	3, 520	6, 380	--------	--------	15 Sept.	--------	

Thorax + Extremity Wounds

47	12 June	68. 8	38	1, 350	2, 280	3, 630	16, 500	66	12 June	5, 500	Carbine wds.—Perf. lung rt. axill. vein and art., mod. and ulnar nerve.
	--------	------	38	1, 740	2, 900	4, 640	1, 000	--------	14 June	--------	
	--------	------	42	1, 980	2, 750	4, 730	500	--------	17 June	--------	
48	11 July	83. 0	40	2, 180	3, 450	5, 730	3, 000	85	15 July	6, 700	Mine injury — Perf. lung, arm, brachial plexus, cp'd. fract. clavicle, small wd. of face.
	--------	------	39	--------	--------	--------	9, 750	75. 5	--------	--------	

Table 1B. Blood Value Determined With T-1824—Continued

Case No.	Date injured	Weight (kilo)	Hemat.	TRCV (cc.)	Plasma volume (cc.)	Blood volume (cc.)	Blood received (cc.)	Percent normal	Date of volume	Estimated normal (cc.)	Wounds
					Miscellaneous Wounds						
49	1 July	80.0	36	1,970	3,650	5,620	4,000	88	2 July	6,400	Mortar wd.—Perf. of lung, arm, massive wound of liver.
	--------	------	32	1,800	4,000	5,800	--------	--------	14 July	--------	
	--------	------	33	1,360	3,020	4,380	--------	--------	7 Aug.	--------	
50	2 July	------	63	4,080	2,650	6,730	6,000	--------	2 July	--------	Mortar wds.—Cp'd. comm. wd. of mandible c̄ destruct. of jaw. Massive hemorrhage. Devel. pulm. edema. Admitted in shock.
51	4 Aug.	80.0	52	2,270	2,080	4,350	2,000	69	4 Aug.	6,400	S. Frag.—Perf. lung, diaphr. and liver. Massive wd. of liver. Small wds. of lower extrem. and arm.
			45	2,100	2,600	4,700	--------	--------	7 Aug.	--------	
52	26 Aug.	70.5	46	2,390	2,920	5,210	--------	93	26 Aug.	5,600	S. F.—Perf. of heart c̄ peric. tamponade. Perf. of lung. Fract. ribs. Perf. diaphr., stomach, small bowel, colon, spleen, left kidney. Cp'd. comm. fract. left humerus, tibia.

53	20 Sept.	53. 8	44	1, 420	1, 960	3, 380	16, 000	72	21 Sept.	4, 700	Mortar wds.—Multiple wds. of small bowel, perf. of colon, liver, lung and femoral artery. Traumat. amp. left calf at knee. Traumat. small soft tissue wds.
	----------	------	40	1, 680	2, 510	4, 180	1, 500	---------	22 Sept.	---------	
	----------	------	48	---------	---------	---------	7, 000	80. 5	----------	---------	

Table 2. Blood Volume as Related to Time of Sampling

Case No.	Early samples		Late samples		Difference
	Time interval (minutes)	Volume	Time interval (hours)	Volume	
4	20, 40	3, 280	1, 2	3, 660	380
9	15, 30, 45	3, 960	22	4, 064	104
10	20, 40, 60	3, 208	6, 14, ¾, 28	4, 773	1, 565
12	20, 40	3, 660	1, 2½	3, 660	0
18	20, 40	3, 835	1, 5	4, 055	220
21	40, 60	4, 790	1¾	4, 790	0
25	30, 60	4, 400	4½, 5½	4, 775	375
28	No early samples		1, 2, 5	3, 210	
17	20, 40, 60	2, 700	3	3, 373	603

Table 3. Hematocrit Changes During Resuscitation, Operation and Convalescence

Hematocrit

Abdominal Injuries

Patient No.	Admission	Postoperative	Days post operative					
			1	2	3	4	5	6
1	32	52	38	39	39	40		
2	44	42	47	40				
3	40		64	62				
4	50	61	66		65			
5	43	45	50	55	48	47		
6	63 (albumin*)	52 (albumin*)	42	41	47	45	45	
7	34	51	44	40	43	45	45	49
8	48		46		49	43	40	39
9		59	52	49	45	45	43	44
10	41	43	57					

Extremity Injuries

Patient No.	Admission	Postoperative	1	2	3	4	5	6
1	40	43	34		23			
2		41	41	39	36			
3		42	44	38	33			
4	36	35	35	34	29	32		
5	36	44	43	36	31	32		
6		47	44	37	39	32		
7	41	38 (blood*)	47	42	40	36	35	
8	42	44	38	37	36	36		
9	37	35	32	31	33	33		
10	36	35	35	34	29			22

*Intravenous therapy.

Table 4. Comparison of Simultaneous Blood Volumes Determined With Chromium-Labeled Red Cells and T–1824

Case No.	Cr^{51}	Dye	Difference	Diagnosis	Percent difference
3	4, 523	4, 100	−423	(See table 1.)	9. 8
4	3, 280	4, 580	+1, 300		33. 1
	3, 611	4, 920	+1, 309		30. 5
5	3, 832	5, 700	+1, 868		39. 1
9	3, 964	3, 490	−470		12. 8
10	3, 208	3, 995	+787		19. 7
12	3, 660	4, 150	+490		12. 6
16	4, 808	5, 080	+272		5. 5
18	4, 055	3, 940	−115		2. 8
19	2, 581	2, 680	+99		3. 8
20	4, 273	5, 600	+1, 327		26. 8
21	4, 535	5, 540	+1, 005		20. 2
	4, 790	5, 050	+260		5. 3
22	4, 430	4, 470	+40		. 8
29*	4, 071	3, 860	−211		5. 1

*This patient tested preoperatively, therefore not included in table 1.

Table 5. Showing Discrepancy Between Blood Received and Blood Volume Thereafter

(a) Patient No.	(b) Weight (kg.)	(c) Estimated B. V. on admission (cc.) [1]	(d) Volume transfused (cc.) [2]	(e) Postoperative B. V. (cc.) [3]	(f) Deficit (cc.) [4]	(g) Remarks
30	84	2, 700	6, 500	[5] 4, 400	4, 800	Abdominal wound.
32	78	2, 500	7, 500	[5] 4, 600	5, 400	Abdominal wound.
34	65	2, 100	7, 000	[5] 3, 600	5, 500	External wound.
37	61	2, 000	8, 500	[5] 4, 100	6, 400	External wound.
38	--------	2, 500	3, 000	[5] 3, 900	1, 600	See note.[7]
41	78	2, 500	10, 500	[5] 5, 100	7, 900	See note.[7]
5	--------	2, 500	6, 000	[6] 3, 800	4, 700	Abdominal wound.
11	96	3, 000	6, 500	[6] 5, 700	3, 800	External wound.
15	76	2, 500	9, 500	[6] 4, 200	7, 800	External wound.

[1] Estimated as 40 percent of normal.
[2] Volume of whole blood received during resuscitation and operation.
[3] The circulating blood volume measured several hours to 1 day after operation.
[4] Columns (c) and (d) less column (e).
[5] Measured with Evans Blue and hematocrit.
[6] Measured with Cr^{51} and hematocrit.
[7] These patients entered with tourniquets in place above traumatic amputations and underwent uneventful amputations with minimal blood loss and had thereafter only the clean amputation wounds.

Table 6. Red Cell Volumes as Determined with Radio-Chromium

Normal Subjects					
(a) Date	(b) Subject	(c) Weight (Kg.)	(d) Hct. Percent [1]	(e) RBCV, predicted normal (cc.)[2]	(f) RBCV measured (cc.)[3]
2 Dec	A	51	42	1600	[4] 1780
6 Dec			40		1750
4 Dec	B	89	45	2750	1900
11 Dec			40		1820
7 Dec	C	65	44	2000	2560
9 Dec	D	71	44	2200	1860
13 Dec			45		1870
11 Dec	E		46		2180

[1] Hematocrit determined on the specimens taken for Cr^{51} determination.
[2] Red blood cell volume expected on the basis of 30 cc./Kg. body weight.
[3] Red blood cell volume measured.
[4] Female.

Table 7. Red Blood Cell Volume Response to Transfusion, Measured with Evans Blue

(a) Case No.	(b) RBC received (cc.) [1]	(c) △ RBC observed (cc.) [2]	(d) △ RBC-RBC received (cc.) [3]	(e) Percent of RBCV [4]	(f) Percent of RBC received [5]
Fresh Blood Received					
47	450	+390	−60	4. 0	−13
	225	+240	+15	. 8	+6
30	450	+480	+30	1. 7	+6
37	675	+290	−385	28. 0	−58
38	450	+300	−150	10. 8	−33
	675	+660	+15	. 8	−2
40	2, 250	+1, 710	−540	36. 0	−23
41	675	+350	−325	16. 0	−48
Bank Blood Received					
31	450	+210	−240	3. 9	−53
40	225	+230	+5	. 5	+2
53	675	+260	−415	37. 0	−62
43	675	+1, 065	+390	35. 0	+58

[1] Red cells received by transfusions between measurements of the plasma volume.
[2] The change in red cell volume as measured by plasma volume and hematocrit determinations before and after transfusion.
[3] The difference between columns (a) and (c).
[4] Column (d) expressed as percent of the total measured red cell volume.
[5] Column (d) expressed as percent of the transfused red cell volume.

TUESDAY MORNING SESSION

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THE SAFETY OF BLOOD TRANSFUSION IN THE TREATMENT OF MASS CASUALTIES*

Lieutenant Colonel William H. Crosby, MC

In Korea, for the first time, the transfusion service in support of a fighting army was able to provide ample amounts of fresh whole blood wherever it was needed: in mobile surgical hospitals supporting the combat divisions and even at battalion aid stations during periods of heavy action. Medical officers learned that large, rapid transfusions given early could save the lives of many of the most desperately wounded. But some observers, looking beyond these excellent results, expressed disquieting fears that the transfusion of such amounts of blood—especially stored blood—might of itself be injurious. The U. S. Army Surgical Research Team installed at one of the forward hospitals undertook, among other problems, a study of the effects of blood transfusions in battle casualties. They examined the problems of "overtransfusion," pigment metabolism, hemostasis, potassium and citrate intoxications and the relation of transfusion to acute renal insufficiency. Results of these studies are most reassuring. The quality of blood delivered to Korea was good, and transfusion as a therapeutic instrument was not abused. In fact it was found that the requirements for transfusion of the severely wounded were rather consistently, though not seriously, underestimated. The fears regarding injury from transfusion proved, on the whole, to be groundless.

Even as vigilance is the price of freedom, so it is also the price of a good transfusion service. Every transfusion involves certain dangers, and the vigilance of those who operate a transfusion service keeps the danger to a minimum. This is difficult enough when a single hospital encompasses the transfusion service, but difficulties multiply when the service is spread throughout a theater of war. The agency supplying the combat zone has a responsibility to provide blood that is:

1. Adequate in quantity and delivered frequently.
2. As fresh as possible.
3. As well preserved as possible.
4. As safe as possible.

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

We shall consider only the last part of this problem, the safety of the blood as it is provided and also as it is used.

Universal Donor Blood. In the Korean experience incompatible transfusion reactions were almost completely obviated by the decision to use only group O, Universal Donor Blood. Thus, one type of blood was given to all recipients irrespective of their individual blood groups. The plan has much to commend it.

1. Transfusions may be started without waiting for cross-matching.
2. Skilled personnel for cross-matching are not needed.
3. An adequate blood bank can be maintained with fewer units of blood than are required when all types of blood must be provided.
4. Small stocks of blood may be established and used in remote aid stations.
5. The Army in the field is relieved of the responsibility of assuring the compatibility between donor and recipient.

The value of Universal Donor Blood resides in the fact that its red cells possess no antigens that may be attacked by the spontaneously occurring antibodies of the ABO blood group system. There is no incompatibility directed at the donor red cells (figs. 1A and B). The donor plasma, however, contains anti-A and anti-B antibodies. These are incompatible with the red cells of A or B recipients but usually do no damage because they are rapidly dispersed, diluted and neutralized during the course of the transfusion. Even so, the indiscriminate use of Universal Donor Blood is unsafe because a few of these donors possess antibodies of high titer or great virulence so that transfusion of their *plasma* may provoke a severe hemolytic reaction in a recipient of group A, B, or AB (fig. 1C). (The group O recipient is safe because there is no incompatibility.) It is necessary to eliminate the "dangerous universal donors" from the panel of a transfusion service that depends on Universal Donor Blood. The meticulous laboratory control of the transfusion service that supported the Korean war was carried out at Travis Air Force Base, California, and at the 406 Medical General Laboratory in Tokyo where the blood collected in the United States and Japan was processed. It cannot be overemphasized that under this system the prevention of incompatible transfusion reactions in the combat zone rests entirely upon the laboratory control at the blood donor centers. To prevent such reactions two tests were essential:

1. Verification of blood group to be certain that no weakly-reacting bloods of group A or B had mistakenly been labeled group O.

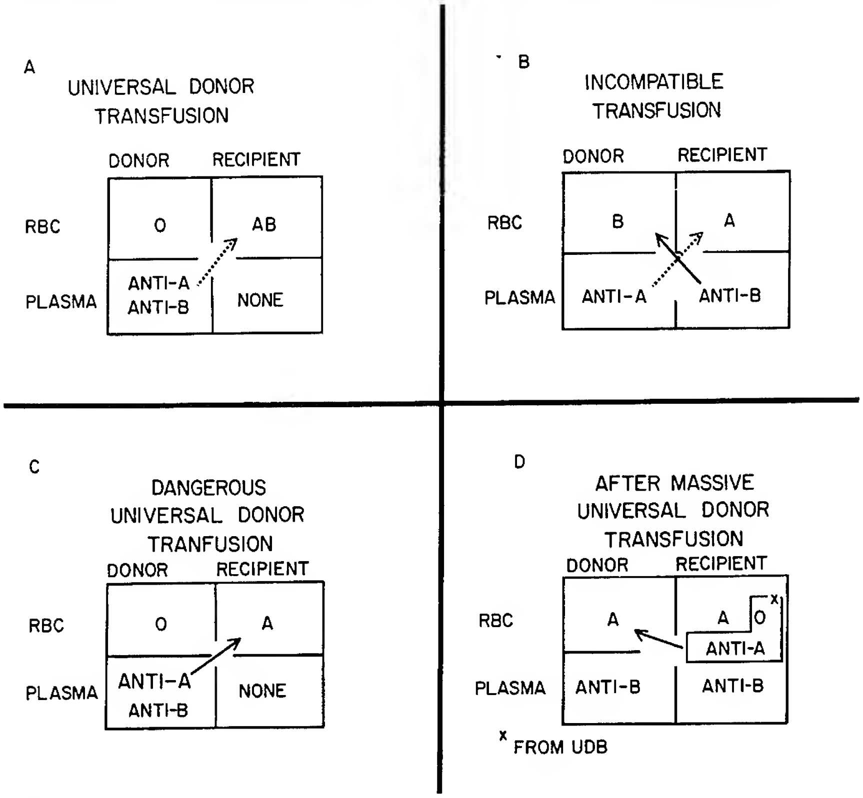

FIGURE 1. Solid arrow indicates an incompatibility between plasma and red cells that can cause a severe transfusion reaction. Dotted arrow indicates an incompatibility of no clinical significance. UDB stands for Universal Donor Blood.

2. Establishment of the titer of anti-A and anti-B antibodies in the plasma of each unit of blood to eliminate dangerous universal donors.

The second was accomplished by a screening test of the agglutinating antibodies. Serum was diluted with saline 1:200 or 1:250, and a mixture of A and B red cells was suspended in it. If agglutination occurred, the blood was labeled HIGH TITER. Where no agglutination occurred, the blood was considered to be low titer and safe Universal Donor Blood.

About 15 percent of the blood sent to Korea was high titer. It was plainly marked as such with an additional admonition "To be used only in group O recipients." Much of this blood was not used and became outdated. The medical officers suspected that it was dangerous, or somehow off color, and refused to accept it, even for group O recipients. Although their reasons for this were more intuitive than rational, they were right to refuse. The blood group that is

stamped on a soldier's dogtag is incorrect in 15 percent of the cases. If a group A man, improperly identified as group O, were transfused with high-titer blood he might possibly have a severe transfusion reaction due to the imcompatibility of the plasma (fig. 1C). Before the war came to a close it had been recommended that only low-titer group O blood be provided for the combat zone.

Parenthetical to this discussion, it should be pointed out that we need a better test to identify dangerous universal donors. By the present standards only 55 to 65 percent of group O donors can be classified as low titer. The others are not all "dangerous" yet the test is intended to eliminate only those who are. It errs on the side of caution. Several types of antibodies are involved in incompatible transfusion reactions: agglutinins, hemolysins, incomplete antibodies and perhaps others. Blood is classified as high titer or low on the basis of an agglutination test because, of the several sorts of antibodies, the agglutinin is easiest to demonstrate. However, the agglutinin itself is not the dangerous antibody. Hemolysins and incomplete antibodies are believed to be the ones that cause reactions. The agglutinin test eliminates dangerous donors because a high titer of hemolysin is usually associated with a high titer of agglutinin. The lack of selectivity of this procedure wastefully restricts the panel of universal donors. For this reason, it is important to characterize the dangerous universal donor more completely and then to devise a precise test to identify him.

The Surgical Research Team found that even low-titer Universal Donor Blood, when used in large amounts, is not without some effect upon the red cells of the recipient. A group A patient who received 15 or 20 pints of group O blood would be found immediately after the transfusion to have about 70 percent of his native red cells replaced by donor cells. (This was demonstrated by using anti-A typing serum to agglutinate the group A cells. The group O donor cells remain unagglutinated and can be counted in the usual manner.) Subsequently the proportion of donor cells would increase without any further transfusion. This meant that the native group A red cells were being eliminated. Sometimes all of them disappeared, so that a patient of group A would be found to have practically 100 percent of group O cells in his blood. The selective loss of his own cells after bleeding and transfusion had ceased was undoubtedly due to the activity of the anti-A antibodies in the plasma of the donor blood. It is emphasized that the hemolysis was a gradual process. It was not associated with an abrupt, shocking reaction of the sort encountered after incompatible transfusions. Clinically one could not tell that a hemolytic process was at work, and the patients suffered no obvious harm.

In some men who received large transfusions of Universal Donor Blood it was possible to demonstrate the persistence in their plasma of incompatible antibodies that had been tranfused into them. For example, a patient of group A might be found to have anti-A agglutinins in his blood. Although this situation—as pointed out above—was of little clinical detriment, it was recognized to be a source of potential danger to the patient. Medical officers at forward hospitals in Korea sometimes deemed it desirable to provide fresh blood for men who had received large amounts of bank blood, and in ordering such transfusions they often asked that group-specific blood be obtained. The laboratory technician was then confronted with the problem of determining the blood group of a patient whose blood contained two sorts of red cells: the group O universal donor cells and those of his hereditary group. Sometimes there were so few of his own that the typing serum would produce only a few pinpoints of agglutination, a difficult result to interpret. The cross-match was equally difficult when the presence of "foreign" antibodies would cause agglutination of blood cells of the patient's own group. This indicated that the patient could no longer be safely transfused with blood of his hereditary group. The passively acquired antibodies were incompatible with his own blood group. Suppose now the technician after testing 20 donors, decides that several of the cross-matchings looked less incompatible than the others and releases those units of blood for transfusion. An incompatible transfusion reaction might result (fig. 1D).

The same accident may happen in a more subtle way. For example, a severely wounded man was admitted to a surgical hospital. It was apparent that he would require many units of blood during the period of resuscitation and surgery. It was decided to use, in part, fresh, group-specific blood, and blood for cross-matching was taken from the patient. Donors were called from nearby troop units. Six of them were cross-matched against the patient and were bled. This required several hours to complete. Meanwhile the patient had received 18 pints of Universal Donor Blood. When the fresh blood was begun the patient went into shock and his plasma was found to be stained dark red with hemoglobin, the obvious signs of an incompatible transfusion reaction. Unfortunately, the patient's red plasma was not examined for the antibodies that might have caused the reaction.

Because of this danger, the Department of the Army has issued a transfusion precaution: "The use of group-specific blood may be dangerous following large transfusions of group O, Universal Donor Blood, causing severe hemolytic reactions. In any instance where multiple transfusions have been made with group O blood, subsequent

transfusions given within a period of 2 weeks following the initial transfusion will be with group O blood."

Rh-positive blood was the only type used in Korea. As a consequence of this, about half of the Rh-negative patients who received transfusions developed anti-Rh (anti-D) antibodies. The use of Rh-positive blood in Rh-negative recipients involves no threat of an incompatible transfusion reaction unless the recipient has been immunized against the Rh antigen prior to the transfusion. Such immunization requires preliminary transfusion or pregnancy both of which are unlikely in a population composed almost entirely of healthy young males. Where civilian populations are involved the problem is more difficult. While it is not desirable to immunize against the Rh antigen any women with child-bearing potential, still one is left no choice when he must decide between immunization and the saving of life. The case of mass casualties inevitably requires some compromises and decisions are often dictated by expediency. A woman should not be permitted to die while her blood is typed and cross-matched.

The establishment of a blood donor service in the Korean combat zone was suggested from time to time during the war. This was not undertaken for several reasons:

1. An Army in the field should not be required, except under extreme conditions, to provide its own supplies.
2. It is difficult in the field to maintain the standards of sterility, technical excellence and detachment that are the minimal requirements of such a service.
3. The service would be vulnerable to enemy action. A blood depot can be re-established in a few hours by bringing up more blood but a blood donor service with its essential laboratory and skilled technicians can not be quickly or easily replaced.

It was mentioned previously that a small quantity of blood had been obtained locally in Korea from our own troops and was used in the Army surgical hospitals. It is believed that most of the incompatible transfusion reactions that occurred were a result of the use of this sort of blood. In 1952 only four patients were admitted to the Renal Treatment Center in Wonju with a history or evidence of post-transfusion hemoglobinuria and renal insufficiency. In all four patients the reaction had been associated with the administration of blood procured locally. The laboratory of a mobile hospital is not intended and is not equipped to operate a blood procurement service and the technicians are not trained well enough to be relied upon. The danger outweighs any value that fresh blood may have over stored

blood. Excepting emergencies, the local procurement of blood in the combat zone is not recommended.

The use of cadaver blood was considered but not investigated. This source of blood is unattractive for more reasons than an esthetic one.

1. The killed in action are usually widely dispersed and priority of recovery must be given to the living wounded.
2. Most of those killed in action die as a result of cutting a major blood vessel, hence much of the blood could not be recovered.
3. Bacterial contamination of blood remaining in the body after death from gunshot wounds would be a hazard.
4. The objections, outlined above, to the local procurement of blood in the combat zone apply with equal force here.

Recognition of transfusion reactions is a problem that troubles every good transfusion service. The clinician who administers the blood is not always discriminating. Sometimes he fails to report reactions and sometimes he assumes that any coincidental fever or chill is due to the transfusion. Without a careful examination of each case suspected of a reaction, even an expert can be wrong. One visitor to the hospitals in Korea reported that the rate of transfusion reactions was probably high because patients receiving transfusions were observed to shiver and some patients after transfusion passed dark urine. The Surgical Research Team formed a different opinion. They examined the blood of such patients and found no evidence of transfusion reactions. It should be noted that shivering may be due to cold and that severely wounded patients were rapidly transfused with ice-cold blood. Shivering can also be due to bacteremia, a condition that is not unexpected in casualties with extensive, heavily contaminated wounds. Dark urine is also to be expected in patients with severe muscle wounds. The pigment that appears in the urine of these patients is myoglobin, not hemoglobin.

On the basis of the observations of the Surgical Research Team it is concluded that the incidence of incompatible transfusion reactions in Korea was exceptionally low. The statistics of the Renal Treatment Center support this. Over 50,000 transfusions were given in Korea in 1952. In that year, as mentioned before, only four patients were admitted to the Center with acute renal insufficiency due to an incompatible transfusion. There probably were more than four reactions: some died and some recovered without going to Wonju. Inquiries found few of them.

Although the rate of incompatible transfusion reactions was low, there are no accurate figures on the subject. This should not happen again. It is important to have a continual examination of the problem. The careful study of each reaction provides information that is needed to prevent subsequent reactions. Even the meager informa-

tion provided by the statistics of the Renal Treatment Center suggested that most, if not all reactions in Korea, were a result of using locally procured blood. To the end of obtaining this essential information two recommendations are made:

1. The personnel who administer transfusions should be well trained to recognize reactions and should know what records to take and what specimens to collect so that the cause of the reaction can be identified.
2. There should be quickly available in the combat zone an expert who can interpret the evidence and identify the cause of the reaction.

Transfusion reactions due to bacterial contamination of stored blood are rare but when they occur they are usually fatal. In most transfusion services in the United States there is no provision for culturing blood that is assumed to be sterile. In a few centers where carefully controlled studies of the problem have been made it has been found that about 3 percent of the units of blood collected under vacuum into glass equipment were contaminated. When blood was collected into plastic equipment, with the donor tube fused to the bag (fig. 2), the rate of contamination was 0.6 percent. These studies were based upon cultures incubated at warm temperatures, and most warm-growing organisms do not grow in the cold. On the other hand, certain cold-growing bacilli do not proliferate in warm cultures although they multiply freely at refrigerator temperatures.

Bacterial contamination does not appear to be an important problem in the United States. In most transfusion services, blood is turned over rapidly, much of it remaining in storage less than 5 days. This reduces the opportunity for bacteria to increase to dangerous numbers. Blood used in the combat zone has been stored longer, and the danger is therefore somewhat greater. With the development of methods to extend further the storage period of bank blood the problem of bacterial contamination may become more serious. Although, in the Korean experience there were no known instances of "transfusion catastrophe" due to bacterially contaminated blood, they may have occurred without being recognized. Under the circumstances, the basis of such reactions would have been difficult if not impossible to prove. Nevertheless, the problem confronts us, and it is one of the most compelling reasons for adoption of plastic blood-collecting equipment. The plastic bag should have the donor set fused to it as an integral part to eliminate the most likely cause of contamination, the trapping of bacterially contaminated air. This type of blood bag permits still another safeguard against the transfusion of contaminated blood. After phlebotomy, the plastic donor tube, sealed at its distal end, remains attached to the blood bag. Before the unit is

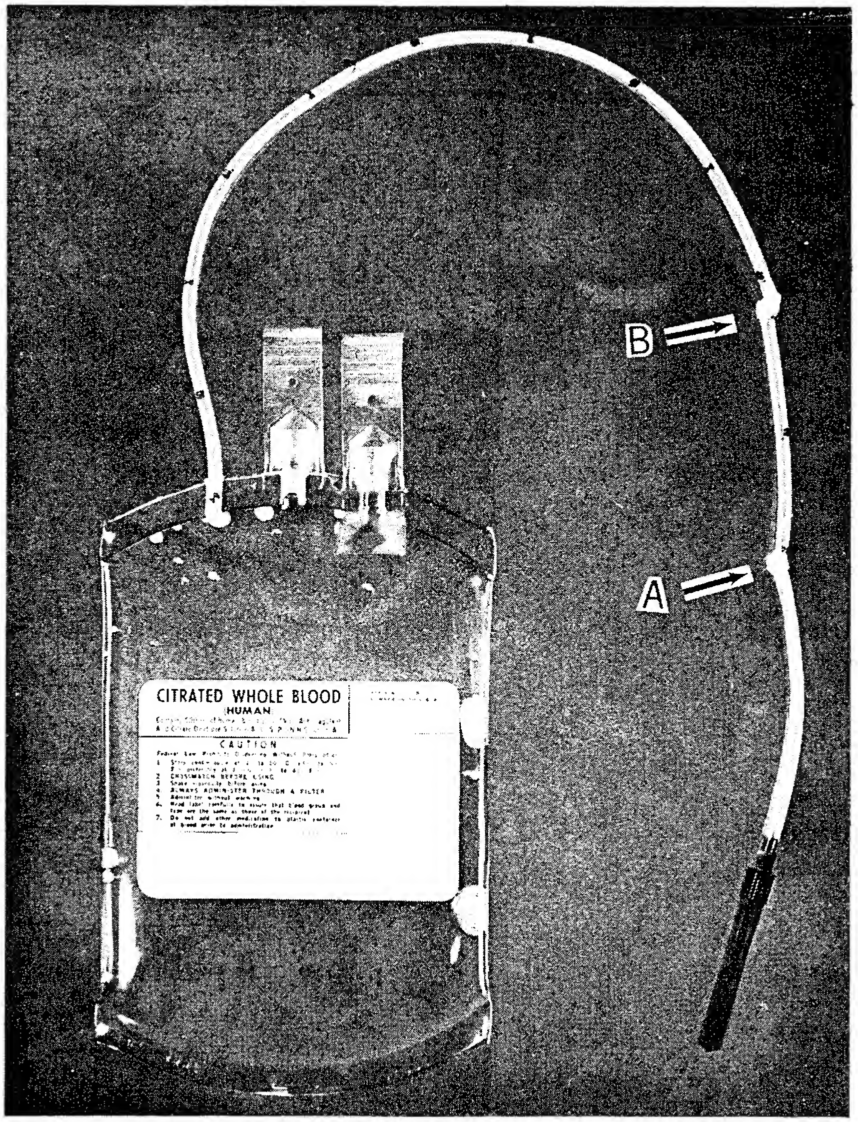

FIGURE 2. Plastic Blood Collection Container with Integral Donor Set.

After the bag is filled with blood one knot is set in the tube (A) and the blood between the knot and the bag is stripped into the bag. Blood distal to the knot can be used for typing. When it is desired to test for bacterial contamination the blood that refluxed to the tube is again stripped into the bag. After the tube has refilled itself, a second knot is set at B. With aseptic care the tube is cut between A and B. The blood obtained can be cultured or otherwise examined for contamination.

used the blood in the tube is milked into the bag and the tube is permitted to refill. Another seal is made in the tube, closer to the bag. The tube is then cut between the two seals and a smear of the blood is stained and examined for bacteria (fig. 2).

Plastic transfusion equipment obviates another source of danger. Rapid transfusion was often necessary to save the lives of severely exsanguinated men. It was the custom in Korea to pump air into the transfusion bottle. The danger, of course, was that of air embolism and to prevent this a technician was detailed to the job of watching the pressure transfusion. When plastic equipment is used pressure is applied not by inflation but by squeezing the collapsible bag.

The adoption of plastic equipment has already been recommended by the three Armed Services and it should become standard within a year. If among its other attributes of less weight, less volume and less breakage, the use of plastic can permit blood to be dropped from aircraft, our transfusion service will become even more flexible.

The use of old blood was once suspected to be a serious fault of the transfusion service in Korea. The blood received at the forward hospitals was 8 to 10 days old and most of it was 10 to 15 days old before it was used. Fears were expressed that the blood might have been injured by its long journey across the Pacific during which the refrigeration could have been interrupted. The blood arriving at the forward hospitals was suspected of containing a high proportion of nonviable red cells, cells that could live in the circulation less than 24 hours. It was suggested that the destruction of these red cells in patients who received large transfusions would produce hemoglobinemia intense enough to damage their kidneys. The work of the Surgical Research Team demonstrated that the blood arriving at the forward hospitals was well preserved (fig. 3), that refrigeration had been well maintained and that the proportion of nonviable red cells was probably not much greater than it is in blood stored for similar periods in the United States. The destruction of these nonviable red cells by the recipient was not associated with significant levels of hemoglobinemia (fig. 4). The cells were lost from the circulation within 24 hours, but the evidence indicates that most of them did not release their hemoglobin into the plasma and their destruction did not throw an excretory burden upon the kidneys of the patient.

Far from being injurious, it seems that "outdated" blood could be of value as a plasma substitute. Hemoglobin comprises 80 percent of the protein of whole blood but it cannot be given as a concentrated solution because of its dangerous vasorenal effects. Given as old blood the hemoglobin is not released to the plasma as such. The patient may receive the blood as an antidote for shock, and even though a high proportion of the cells did not survive for many hours, their protein,

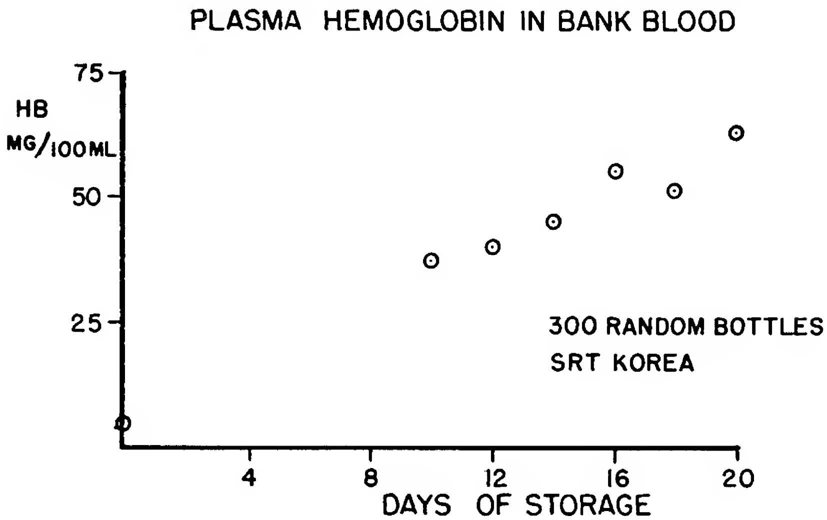

FIGURE 3. The concentration of hemoglobin in the plasma of bank blood is a good index of the care it has received. The values indicated above are agreeably low. Even at 20 days a plasma hemoglobin concentration of 70 mg. per 100 ml. represents the loss of only 0.5 percent of the total red cells in the bottle.

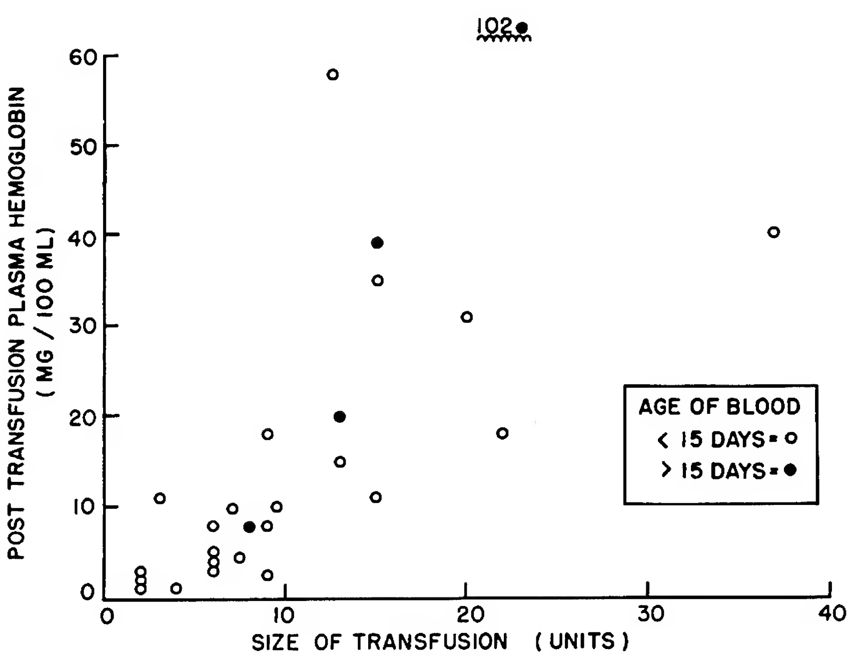

FIGURE 4. Patient's plasma hemoglobin after transfusion with stored blood. Even large transfusions of relatively old blood did not cause hemoglobinuria of a degree apt to be detrimental.

when they are destroyed, becomes available to the patient. There seems good reason to suggest that outdated blood may be useful for treatment of the moderately wounded who require less than 5 units of blood.

Summary

1. The decisions to use Universal Donor Blood in the combat zone in Korea obviated incompatible transfusion reactions. This practice in the handling of mass casualties permits transfusion to begin without delay for cross-matching, and it places the responsibility for compatibility of the transfusion upon the supplying agency in the rear rather than upon those who use the blood under adverse conditions. The few incompatible reactions that occurred in Korea were usually due to blood that had been procured locally in the combat zone.

2. It was found that massive transfusions of Universal Donor Blood in recipients of other groups sometimes resulted in an accumulation of transfused antibodies that were active against red cells of the recipient. This made it unsafe to transfuse the patient with blood of his own hereditary group when subsequent transfusions were required. The foreign antibodies required as long as 2 weeks to disappear.

3. The problem of bacterial contamination of stored blood did not appear to be the cause of reactions, but the matter deserves study as to how best to prevent or control it. The use of plastic bags is expected to improve this situation.

4. The use of old blood, even in large amounts rapidly given, caused little if any damage that could be attributed to the age of the blood. Declaring stored blood to be outdated after 21 days seems a reasonable precaution, but it is suggested that well refrigerated blood up to 60 days of age may be employed as a "plasma substitute" in the less severely wounded.

MASSIVE TRANSFUSIONS, BLOOD DERIVATIVES AND PLASMA EXPANDERS*

Major Curtis P. Artz, MC

Experiences of World War II pointed out the value of whole blood in the management of severely wounded. As the Korean conflict progressed, it became apparent that large quantities of blood should be administered to the battle casualty. In a survey of 995 consecutive casualties admitted between February and August 1953 to the general surgical service of the 46th Surgical Hospital in Korea, 138 (or 14 percent) required replacement of 5 or more pints of blood. During the first 24 hours, 27 (or 3 percent) of these 995 casualties required over 15 pints of blood and plasma expander. Admissions totaled 684 American casualties and 311 Korean casualties. Mortality rate for the American patients was 2.2 percent, and for all general surgical casualties, the overall mortality rate was 3.2 percent.

Casualties Who Received 5 or More Pints of Blood

The mortality rate in relation to blood requirement in the group of 138 patients is outlined in table 1. As the blood requirement increased, the mortality rate increased. Twenty casualties died and, of this number, 16 died within the first 48 hours. Of the 122 patients who survived for 48 hours, 6 developed a marked degree of renal insufficiency and 4 of these died.

Table 1. Mortality Related to Blood Requirement (February to August 1953)

Amount of blood given	Number of patients	Deaths	Mortality (percent)
5–10 pints	61	1	1. 6
10–15 pints	50	8	16. 0
15–20 pints	12	3	25. 0
20–56 pints	*15	8	53. 3
Total series	†138	20	14. 5

*Only 10 lived more than 48 hours.
†Only 122 lived more than 48 hours.

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

Mortality and Type of Injury. The mortality rate in relation to the type of injury is outlined in table 2. Casualties whose injuries were primarily in the abdomen had a mortality rate of 16 percent. In the group whose injuries were primarily in the extremities, the mortality rate was 10 percent. Casualties sustaining thoraco-abdominal wounds had a higher mortality rate (26.6 percent); while for those who had chest wounds it was 9 percent.

Table 2. Mortality Related to Type of Injury

Type of injury	Number of patients	Deaths	Mortality (percent)
Abdomen	60	10	16. 0
Extremity	52	5	10. 0
Thoraco-abdominal	15	4	26. 6
Chest	11	1	9. 0
Total	138	20	14. 5

Resuscitative Fluids during Various Phases of Care. The amount of blood or colloid solution given prior to admission to the hospital is summarized in table 3. Eighty-one of the 138 patients received resuscitative fluids, predominantly dextran; but some received modified fluid gelatin, albumin and blood. Patient in the 5- to 10-pint group received about 1 pint of blood or plasma expander, while the patients in the 10- to 56-pint group received about 3 pints of fluid prior to admission.

Table 3. Pre-admission Blood and Plasma Expander

Category	Total number patients in category	Number receiving therapy pre-admission	Average amount received pre-admission* (cc.)
5–10 pint group	61	38	685
10–56 pint group	77	43	1, 440
Entire series	138	81	1, 090

*Mostly dextran.

The average amount of blood replacement during various phases of resuscitation is shown in table 4. Patients in the 5- to 10-pint group were given an average of 3,440 cc. of fluid therapy during the first 24 hours after injury. Those requiring 10 to 35 pints averaged more than twice as much as those in the first group, namely, 7,300 cc. In

each group the amount of blood given preoperatively was essentially the same as the amount given during the operation. Of the 73 casualties in the 10- to 35-pint group, 38 received an average of 1,130 cc. of resuscitative fluids postoperatively; and of the 61 casualties in the 5- to 10-pint group, 18 received 720 cc. of fluids.

Table 4. Blood Replacement During Phases of Resuscitation

Category	Number receiving therapy	Amount prior to operation (cc.)	Amount during operation (cc.)	Amount postoperative (cc.)
5–10 pint group				
Total patients—61	59	1, 770	----------	----------
Average total blood in first 24 hours—3,440 cc	55	----------	1, 500	----------
	18	----------	----------	720
*10–35 pint group**				
Total patients—73	67	3, 400	----------	----------
Average total blood in first 24 hours—7,300 cc	66	----------	3, 200	----------
	38	----------	----------	1, 130

*For more accurate sampling 4 patients who received 40, 46, 52, and 56 pints of blood were excluded.

Fifty percent of the patients in the abdominal group and 48 percent of the patients in the extremity group were given approximately 1 liter of plasma expander in addition to blood. Most of this plasma expander was administered before these patients arrived at the hospital.

Control of Hemorrhage. Hemorrhage was controlled preoperatively in all 61 casualties in the 5- to 10-pint group. Of the 77 casualties in the 56-pint group, hemorrhage was not controlled prior to operation in 13; and control of hemorrhage preoperatively was questionable in 8. Of these 21 patients, hemorrhage was brought under control at operation in all but 4. Two of these four patients died on the operating table (one had a large laceration of the common iliac artery and the other had a high bilateral amputation of the thigh). One patient with a massive liver wound died during the first postoperative day because of uncontrolled bleeding. The fourth patient had a massive liver and retroperitoneal muscle wound. He continued to bleed after operation, requiring 875 cc. of blood per hour to replace the blood lost. His wound was re-explored 4 hours after the first operation. There were multiple bleeding sites in the retro-

peritoneal area; and this area was packed with two 5-yard-roll gauze packs. The oozing did not stop, however, until after 6 pints of fresh blood was administered. The patient subsequently recovered. During the first 24-hour period, this patient was given 46 pints of blood. In three other casualties with uncontrolled hemorrhage preoperatively, the major points of hemorrhage were controlled at operation. Oozing continued from all surfaces and these three casualties died after several hours, having received 35, 52, and 56 pints of blood respectively.

Patients Admitted in Shock. In the group of 138 most severely wounded casualties, 33 were admitted in severe shock; and of this number 7 died (table 5). Severe shock was a clinical diagnosis. Each of the 33 casualties had a systolic blood pressure of 80 mm. of mercury or less. The type of wound varied; but no particular type of injury predominated. The average time of evacuation was 2 hours and 20 minutes. The total amount of blood given in the first 24 hours ranged from 2,500 cc. to 28,000 cc. The average amount of blood administered preoperatively was 4,300 cc., averaging 7,600 cc. for the first 24 hours.

Ten casualties in this group were admitted with a blood pressure that was too low to be obtained by the usual cuff method. Three of these died; two died from uncontrolled hemorrhage, and the cause of death of the other was unknown. The seven casualties who lived required from 11 to 26 pints of blood in the first 24 hours.

The causes of three of the other four deaths in this severely shocked group were cardiac arrest, refractory postoperative shock and uncontrollable oozing, and in one instance the cause of death could not be determined. In the 33 most severely wounded casualties who were admitted in severe shock and required an average of 15 pints of blood, the mortality rate was 21 percent.

Deaths. There were 20 deaths in the group of the 138 most severely wounded casualties (table 6). Most of this group were held at the hospital for a period of from 5 to 8 days; and they were evacuated only after their condition became stable. Soon after injury, a few were evacuated to the Renal Insufficiency Center at the 11th Evacuation Hospital because of post-traumatic renal insufficiency. Deaths listed included those that occurred at the 46th Surgical Hospital and at the Renal Insufficiency Center. Renal failure was not listed as a cause of death in these patients because it was considered a contributing factor rather than a primary cause of death.

Causes of death were determined by clinical review of the case histories and autopsy findings.

Table 5. Very Severely Wounded—Admitted in Severe Shock, 33 Patients—7 Deaths—Mortality 21 Percent

No.	Patient	Type wound	Evac. time minutes	Admission blood pressure	Preoperative blood in cc.	Blood total first 24 hours in cc.	Remarks
1	S. D. K.	Ext.	110	70/30	2,000	2,500	Recovered.
2	L. J. B.	Ext.	105	80/40	2,000	3,000	Recovered.
3	J. C. D.	Abd.	180	70/40	2,500	3,000	Recovered.
4	P. Y.	Ext.	120	40/0		3,500	Recovered.
5	L. N. W.	Abd.	60	66/0	2,000	3,500	Recovered.
6	C. J. S.	Ext.	270	80/40	2,0[illegible]0	4,000	Recovered.
7	H. C.	Abd.	185	60/30	2,500	4,000	Recovered.
8	N. E.	Ext.	270	70/40	3,750	4,750	Recovered.
9	L. S. C.	Chest		60/0	2,500	3,500	Recovered.
10	A #1	Abd.		40/0	3,000	5,000	Recovered.
11	J. A.	Thor-Abd.	150	80/40	3,000	5,000	Recovered.
12	C. S. W.	Abd.		70/40	4,000	5,500	Recovered.
13	A. B. S.	Ext.	120	70/40	3,500	6,000	Recovered.
14	C. F.	Ext.	195	80/0	5,500	6,500	Recovered.
15	W. D.	Ext.	45	70/30	3,000	7,000	Recovered.
16	G. H.	Ext.	170	70/40	2,500	7,000	Recovered.

17	Y. M. S	Abd	130	70/0	4, 000	9, 000	Recovered.
18	J. K	Abd	90	70/40	5, 000	10, 000	Recovered.
19	K. Y. S	Abd	90	74/52	3, 500	11, 500	Recovered.
20	K. J. B	Ext	103	0/0	5, 500	5, 500	Recovered.
21	F. M	Abd	180	0/0	4, 000	6, 000	Recovered.
22	T. R	Ext	120	0/0	6, 000	6, 000	Recovered.
23	H. B. S	Chest	190	0/0	4, 000	7, 000	Recovered.
24	W. W. S	Abd	180	0/0	6, 500	8, 500	Recovered.
25	P. K. C	Abd	----------	0/0	2, 500	11, 000	Recovered.
26	D. J. P	Chest	70	0/0	5, 500	13, 000	Recovered.
27	C. C. S	Thor-Abd	205	0/0	4, 000	8, 000	Expired, unknown.
28	M. H	Abd	105	0/0	5, 500	9, 000	Expired, uncontrolled hemorrhage.
29	J. M. J	Ext	125	0/0	12, 000	16, 000	Expired, uncontrolled hemorrhage.
30	G. G. C	Ext	330	80/60	2, 500	6, 000	Expired, cardiac arrest.
31	T. K	Ext	90	80/60	5, 500	9, 500	Expired, postoperative shock.
32	J. J	Ext	85	40/0	5, 500	11, 500	Expired, undetermined.
33	P. T	Abd	180	50/30	12, 000	28, 000	Expired, uncontrolled oozing.
Averages			140	----------	4, 300	7, 600	

Table 6. Cause of Death

Causes*	Number of deaths	Causes*	Number of deaths
Uncontrolled oozing postoperatively	4	Pancreatitis	1
Postoperative shock	3	Septicemia	1
Uncontrolled hemorrhage	3	Aspiration pneumonia	1
Peritonitis	2	Undetermined	1
Cardiac arrest	2	Unknown	1
Massive lung damage	1	Total	20

* Post-traumatic renal insufficiency was a complication in four patients of this series.

Casualties Who Received 15 or More Pints of Blood or Plasma Expander

During 1952 and the first half of 1953, a study was made of 89 battle casualties during the first 24 hours after injury. Each of the casualties required a minimum of 15 pints of blood or plasma expander, or one and one-half times the normal blood volume. Included in this group of 89 casualties were those from the previous group of 138 casualties who required 15 or more pints of blood or plasma expander.

Some patients received 30, 40, and even 50 pints of resuscitative fluids within the first 24 hours. Of the patients who received more than 15 pints of blood or plasma expander, the mortality rate was 44 percent (table 7).

Table 7. Mortality—Casualties Who Required 15 or More Pints of Blood and Plasma Expander

Injury	Number	Number died	Mortality (percent)	Number dying of continued hemorrhage	Mortality excluding continued hemorrhage (percent)
Abdomen	24	19	79	11	61. 5
Abdomen and extremities	29	12	41	3	35
Extremities	29	5	17	1	14
Chest	7	3	43	1	33
Total	89	39	44	16	31. 5

Massive Transfusions

The successful use of massive transfusions re-emphasizes certain lessons learned in World War II, namely, that the treatment of wound shock is primarily the control of hemorrhage and the administration of adequate quantities of blood. One of the primary differences in resuscitation during the Korean conflict and during World War II was the difference in the amount of blood administered. Massive transfusions were used frequently and only rarely was there evidence of overtransfusion. From the data on blood volume determinations after massive transfusions collected by Captain Theodore Prentice, it appears that large quantities of blood were lost from the effective circulation. In most instances, recovery from the initial hypotension followed the administration of large quantities of blood. An occasional patient who reached the hospital alive, but who had vital organ damage, succumbed even though there was only a minimal blood loss. This was most frequently observed in casualties who had injuries of the brain. In general, the severity of the injury was in direct proportion to the amount of blood lost. Both the injury and blood loss continued to exert a deleterious effect.

Blood Derivatives

Lyophilized pooled plasma and serum albumin were used as emergency shock solutions during the early phases of the Korean conflict. Plasma had two undesirable aspects, namely, a high percentage of the bottles contained the virus of serum hepatitis, and a large number of bottles were broken during cold weather. Approximately 20 percent of the patients in Korea who received pooled plasma subsequently developed homologous serum hepatitis. Many of the battalion surgeons complained that the water used for reconstitution of the plasma froze during the cold weather and bottles were broken. Serum albumin was used: 100 cc. of 25 percent solution. Its particular advantage was its availability in small containers which were easily carried by the aidman. Comparatively little dependable information is available on the efficacy of albumin. The battalion surgeons, however, generally believed albumin to be a satisfactory resuscitative agent for emergency treatment.

Plasma Volume Expanders

Dextran replaced plasma and serum albumin in many division areas toward the end of the Korean conflict. Two thousand units of dextran were administered to approximately 1,000 casualties. No toxic reactions were observed. Part of the material was used at the

division level—prior to admission to a forward hospital—as an emergency plasma volume expander. An equal amount was utilized at forward hospitals in patients who had wounds of minimal severity; and these patients were resuscitated entirely with dextran. Some dextran was utilized with blood as a resuscitative agent in patients having more severe wounds.

The Surgical Research Team in Korea studied 19 battle casualties in order to determine the fate of infused dextran. Severely injured patients were given 1,000 cc. of dextran in the immediate postoperative period. This infusion required from 2 to 4 hours. Immediately after infusion, approximately 40 percent of the dextran was present in the plasma. Three hours after infusion, approximately 28 percent of the dextran remained in the circulation. Six hours after infusion, 22 percent of the dextran remained in the plasma; and 12 hours after infusion, 16 percent remained. Only from 2 to 3 percent was still present in the plasma at the end of 72 hours. It must be pointed out that the dextran used in this study was of lower molecular weight than is presently acceptable, having an average molecular weight of 43,000.

The loss of dextran from the circulation appears to be directly related to urinary excretion. After 3 hours, approximately 37 percent of the infused material was found in the urine; after 6 hours, 42 percent; and after 24 hours, 54 percent. Thereafter, dextran was excreted in small amounts. Approximately 30 percent of the dextran administered could not be accounted for in the plasma or urine. This unaccounted-for fraction was presumably lost into the wound, the extravascular compartment, or possibly metabolized.

In a similar study, 200 units of modified fluid gelatin were administered to battle casualties. The average molecular weight of this material was 34,000. The quantity of gelatin administered was 1,000 to 1,500 cc. A few patients received as much as 2,500 cc.; and one patient received 3,000 cc. No evidence of toxicity was seen. The gelatin solution flowed freely and, over a period of 8 months in storage, it did not change color. No data are available on the flow of gelatin during extremely cold weather. However, there was no record of difficulty with the administration of gelatin given at the battalion aid stations during the winter months.

The fate of gelatin was studied in 10 patients immediately after operation. Over a 4-hour period, 1,000 cc. was given. At the termination of infusion, approximately 50 percent of the material remained in the plasma, 30 percent having been excreted in the urine. At 72 hours after administration, only from 2 to 3 percent of the gelatin remained in the plasma, approximately 80 percent having been excreted in the urine.

In comparing the fate of dextran and gelatin in two similar patients, it was found that the amounts of each remaining in the plasma—at similar intervals after infusion—were essentially the same. The amount of gelatin excreted in the urine immediately after infusion was slightly higher than the amount of dextran excreted in the urine during a similar period.

Ratio of Dextran to Blood. Dextran was used in conjunction with whole blood on several occasions during the preoperative, operative and postoperative periods of resuscitation. A study was made of 35 patients who received 1,000 cc., or more of dextran, in addition to blood, in an attempt to find a safe and practical ratio of this plasma expander to blood. From these studies, certain trends were observed that would justify a conservative rule as to the ratio of dextran to blood (table 8). If a patient has a blood volume deficiency of from 1,000 to 1,500 cc., he can be entirely resuscitated with dextran. If the deficiency is between 1,500 and 4,000 cc., then a safe ratio is 1 unit of dextran to 1 unit of blood. If the patient requires from 4,000 to 7,000 cc. of fluid for resuscitation, the ratio suggested is 1 unit of dextran to 2 units of blood. In patients who are severely wounded and require over 7,000 cc. of resuscitative fluids during their first 24 hours, a maximum of 2,500 cc. of dextran should be used; while the remainder of supportive fluids given should be whole blood.

Table 8. Acceptable Ratio, Dextran to Blood

Blood volume deficiency	Ratio
1,000–1,500 cc	Dextran alone.
1,500–4,000 cc	1 dextran : 1 blood.
4,000–7,000 cc	1 dextran : 2 blood.
Over 7,000 cc	Maximum dextran–2,500 cc. Remainder blood.

Although 2,000 cc. or more of dextran caused a rather distinct hemodilution, with a rapid fall in the hematocrit, patients tolerated a limited red-cell mass as long as the plasma volume was adequately expanded. Some patients exhibited a rapid pulse for varying periods of time; however, when additional whole blood was given, the pulse rate returned to normal. This concept of a conservative ratio of dextran to blood has wide implications in time of catastrophe when adequate amounts of whole blood are not available. A patient who has a minor blood volume deficiency can be supported adequately by the use of dextran. Likewise, blood may be conserved in more severely injured patients by administration of dextran in an appropriate ratio.

Use of Plasma Expanders at the Division Level. As experiences in Korea accumulated, it became evident that early resuscitation was of considerable value. It was observed that casualties who were prepared for transportation at the battalion level withstood the further injury of evacuation better than casualties who were sent back to a surgical hospital without restoration. Preparation included the administration of a plasma volume expander. After loss of considerable quantities of blood, a battle casualty withstands the trauma of transportation better if his plasma volume is expanded.

Soon it became apparent that the earlier after injury a plasma volume expander could be administered, the better the casualty withstood transportation to an aid station. In several instances, the litter-carry was quite long from point of injury at the forward outpost or from some point on a patrol mission. During this period, the casualty's condition might deteriorate considerably. It was learned that some type of plasma volume expander was quite useful during transport to an aid station. Early in the Korean conflict, serum albumin was utilized for this purpose because it was packaged in a small bottle enabling the company aidman to carry several of these units in his pocket. As dextran was used more extensively, it was found quite useful in the division area when packaged in plastic bags. Dextran—thus packaged, in a small, convenient bag—was carried by company aidmen on patrol so that infusion could be started immediately after a soldier was injured. The use of dextran in plastic bags permitted the early institution of restorative measures and proved to be an important advance in the initial care of severely wounded men.

Summary

Experiments in the Korean conflict pointed out the value of massive transfusions in the management of the severely wounded. The average amount of blood administered to the group of patients who received from 5 to 10 pints was 3,440 cc. The average amount of blood given in 10- to 35-pint group was 7,300 cc. In both groups the amount of blood given prior to operation was approximately equal to the amount of blood given during operation.

The mortality rate in 33 casualties who were admitted in severe shock and who received an average of 7,600 cc. of blood in the first 24 hours after injury was 21 percent.

Lyophilized pooled plasma and serum albumin were used as emergency shock solutions in the early part of the war. Plasma had two undesirable aspects, namely, a high percentage of the bottles contained the virus of serum hepatitis and a large number of the bottles broke during cold weather. Dextran replaced plasma and albumin as an

emergency shock solution toward the end of the hostilities. It was found to be a safe, effective plasma volume expander.

Acknowledgement

The tables and data in this report are from:

Artz, C. P., Howard, J. M., Sako, Y., Bronwell, A., and Prentice, T.: Clinical Experiences in the Management of the Most Severely Injured Battle Casualties. (To be published.)

TUESDAY AFTERNOON SESSION
20 April 1954

MODERATOR
MAJOR CURTIS P. ARTZ, MC

MEDICAL ASPECTS OF BODY ARMOR IN KOREA*

Robert H. Holmes, M. D., William F. Enos, Jr., M. D.,

and

Captain James C. Beyer, MC

The results of ballistic surveys of American casualties in Korean fighting were presented in a previous paper (*1*) which also stressed the urgent need for body armor by combat personnel and discussed its probable effectiveness. The first field trial of body armor in Korea (1951) indicated that it could be worn without interference to combat performance, that the soldiers unanimously desired it, and that an appreciable decrease in casualty rate and also in the severity of wounds received could be anticipated. Since that time body armor has become standard equipment for field forces, both Army and Marine Corps, and has been used by large numbers of troops under combat conditions for a significant period. It is believed that the value of the armored vest in the total medical effort to conserve the fighting strength of our field forces has been demonstrated and that this report on it is not premature.

The causative agents of wounds were carefully evaluated as to relative incidence, wounding potential, physical characteristics, explosion distances, range, probable velocities and chance factor for wounding. Anatomic regional frequency and distribution of wounds were determined under variable tactical circumstances, and comparative data compiled for the killed-in-action, the wounded-in-action, and those dying of wounds in hospitals. A large number of autopsies upon the killed-in-action were performed in order to observe significant phenomena of wound production, such as morphologic characteristics of entrance and exit wounds, missile passage and adjacent trauma, and the varied effects of missiles upon skin, soft parts, bone, hollow organs, solid organs, specific lethal wounds and probable casualty survival time. Finally, Army missions in 1951 and 1952 determined beyond doubt that the field soldier could wear, would wear, and desired to wear the body armor afforded him.

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Classification forbids release of certain data but, in general, the significant observations leading to the adoption of body armor were as follows:

1. The nature and behavior of the wounding agent. It was determined that about 75 percent of wounds are caused by shell fragments; not shrapnel, as they are erroneously called. The mean size of these fragments is less than 50 grains and about 1 cm. in greatest dimension. Distance from the shell explosion is usually from 1 to 25 meters for the wounded-in-action, and probably much closer for the killed-in-action. This impression has been obtained by examining the relative wound incidence per casualty in the two groups and by interrogating the wounded.

2. The probable velocity of a significant percentage of the shell fragments was determined by deduction from certain wound characteristics and was found to fall within a range for which protection could be obtained. It was noted that about 70 percent of all missile wounds were of a penetrating type, that is, having a wound of entrance but no wound of exit, rather than a perforating type or "thru and thru wound." This fact allowed for a fair estimate of the average missile velocity of shell fragments upon the battlefield.

3. The anatomic regional incidence of wounds showed that hits on the thorax and abdomen accounted for about 30 percent of the wounds among the wounded-in-action (table 1), 46 percent among those dying of wounds in a hospital, and 45 percent among those killed-in-action (table 2).

Table 1. Regional Distribution of Wounds in WIA

	Percent			
	Without armor		With armor	
Head	14. 4		14. 2	
Neck	3. 0		2. 5	
Thorax	19. 0	30. 0	8. 7	19. 5
Abdomen	11. 0		10. 8	
Upper extremities	25. 0		28. 3	
Lower extremities	27. 0		35. 0	
Genitalia	0. 6		0. 5	
Total	100. 0		100. 0	
Multiple wounds	53. 0		59. 0	
Small arms missiles	15. 3		15. 4	
Shell fragments	84. 7		84. 6	

Table 2. Regional Frequency of Lethal Wounds (Without Body Armor)

	Percent	
	DOW*	KIA**
Head	25.5	41.5
Neck	3.0	4.1
Thorax	24.0	36.0
Abdomen	22.0	9.4
Extremities	20.5	6.0
Buttocks	5.0	3.0
Total	100.0	100.0

*DOW—died-of-wounds (in a hospital).
**KIA—killed-in-action.

4. Actual field trial in Korea showed that the soldier could carry an additional 6 to 8 pounds, suspended from the shoulder girdle, without interference to combat performance. In addition, he desired this protection and manifested improvement in morale and increase in aggressiveness.

Following these observations, body armor was adopted as a standard item of field equipment and, as quickly as production allowed, was issued to frontline combat personnel. Subsequent wound ballistics surveys have demonstrated the value of this armor as shown by the accompanying statistical chart (table 3).

Table 3. Effectiveness of Body Armor Against Missile Hits

	Total	Shell fragment	Small arms	Unknown
Vests hit by missiles:				
Number	254	184	63	7
Percent	100.0	72.4	24.8	2.8
Missiles hitting vests:				
Number	874	725	123	26
Percent	100.0	82.9	14.1	3.0
Defeated by vest	593	549	30	14
Perforating vest	281	176	93	12
Percent defeated*	67.8	75.7	24.4	53.8
Percent perforating*	32.2	24.3	75.6	46.2
Average number of missiles per vest hit	3.4	3.9	2.0	3.7

*Percentage of missiles hitting vests.

Nylon and Doron, a compressed fiber glass, are the materials presently utilized in the various prototypes of body armor. The first

armored vests used in Korea (1951) were a combination of nylon and Doron, the shoulder girdle being tailored with nylon. This allowed for comfort and mobility. The protective properties of the two materials are essentially the same. Recent vests in use by the Army have been made entirely of nylon. They weigh about 8 pounds and provide a high degree of protection against shell fragments and some degree of protection against small arms fire, depending upon the angle of incidence of the bullet and the range. Bullets hitting at acute angles and/or reduced velocities occurring at the terminus of flights are frequently defeated by the vests. In other instances, the severity of wounds is significantly reduced even though the vest may be perforated.

Because of the widespread use of this armor a relative increase had become apparent in the percentage of head wounds, neck wounds and severe wounds of the extremities. For example, those who have suffered multiple missile wounds, some or one of which could have been lethal if in the thorax or abdomen, survive to reach a hospital with a head wound or severe mutilations and amputations of the extremities. Combat surgeons have also noted that the severity of abdominal wounds has decreased and fewer extensive bowel resections are performed. This increase in survival time actually leads to an additional reduction in killed-in-action because of advanced technics in battlefield recovery and helicopter evacuation. Once a casualty reaches a hospital, modern medicine and surgical care assure him of a 98 percent probability of survival. In addition to the prevention of wounds and reduction in severity of wounds to the thorax and abdomen, a valuable psychological adjunct has accrued in terms of improved soldier morale, for greater confidence in personal safety increases aggressiveness in combat.

Classification forbids detailed discussion, but it can be stated that in a statistically significant number of instances 68 percent of all missile hits on armored vests worn in actual combat were defeated. In other words, two out of every three of all missiles hitting the vests failed to produce a wound. Because of the probability of multiple wounds, this does not necessarily mean that a casualty or a fatality was prevented, but it does mean an absolute reduction in the number of wounds any one of which conceivably could have been fatal or disabling. Since about one-third of all who sustain thoracic and abdominal wounds are wounded in these anatomic regions alone, it follows that there is also an actual reduction in total casualty incidence. It is possible, and now appears to be true, that this reduction in casualty incidence is of approximately the same magnitude for both killed-in-action and wounded-in-action; therefore, a significant change in the KIA–WIA

ratio due to body armor need not be expected. This ratio will remain constant or fluctuate, determined by the relative change in the two magnitudes. The true effectiveness of the vest is a simple expression of the percentage of missiles of all types on the battlefield which hit the vests and are defeated. The determination of the ballistic qualities of present body armor is dependent upon carefully controlled laboratory experiments, and its value on the battlefield is specifically related to the number of missiles which it defeats. This has been shown to be 68 percent.

The body armor in current use has been designed primarily for the reduction of battlefield killed-in-action. Any reduction of wounded-in-action is a gratuitous and natural expectancy. The use of such armor is, and always will be, a compromise between the maximum protection desired and the weight load that can be carried without lowering combat efficiency. Vital anatomic regions—head, thorax and abdomen—must therefore assume unquestioned priority in protection. Improvement of design and search for new materials providing maximum protection with minimum weight are continuous.

It is also cogent to consider the application of similar protective device in the civilian defense program. The battlefield is no longer confined and the spectre of atom-bomb and H-bomb blast upon homeland cities is an accepted prospect. Injury from flying debris, such as masonry, metal and glass, is of great importance following such blast (*2*), and conceivably the use of body armor could lessen appreciably the staggering morbidity and mortality anticipated in such a mass civilian disaster.

Summary

Medical care upon the battlefield is one of the greatest challenges presently before us and it is being met vigorously by prevention of wounds as well as by treatment of wounds. The concept of prevention is of potential value also in meeting the tremendous problem of civilian medical care in the event of all-out war.

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2. Liebow, A. A., Warren, S., and DeCoursey, E.: Pathology of Atomic Bomb Casualties. Am. J. Path. *25:* 853–1027, 1949.

EXPERIMENTAL WOUND BALLISTICS*

CAPTAIN EDWARD W. A. OCHSNER, JR., MC

In the experimental laboratory we have been attempting to develop a standard wound preparation comparable to a lethal war injury. Such a preparation would permit one to: (1) study in detail, and under rigidly controlled conditions, the disturbed pathophysiology associated with wounding, and (2) to compare various types of therapeutic measures that may be applied to the wounded.

The animal we have used in our studies is the goat, chosen primarily because of its size, docility and relative availability.

The animals have been wounded by two methods, each of which is comparable to a slightly different type of war injury. In one preparation a high-velocity missile wound is produced by shooting the animal through the large posterior muscle mass of the upper hind leg with a steel sphere (53.3 grains), traveling at a speed greater than 6,000 ft./sec. The missile produces external wounds of varying size on the lateral and medial aspect of each upper leg, but even when the external wounds are very small, the damage done to the tissues within the legs is always extensive. The second preparation, i. e., the blast injury, is produced by a high-explosive charge called "tetryl" (2, 4, 6 trinitro-phenyl-methyl nitramine). A small cylinder (0.795 inch in diameter and 0.494 inch in depth) is taped to the lateral aspect of each upper hind leg. On top of and in direct contact with the explosive is a detonator cap and the charge is detonated by 0.7 watt of electricity. The typical wound that results is superficially much larger than that produced by the high-velocity missile and even though there is no exit wound on the medial aspect of the thigh, the tissue damage extends through the leg.

These are interesting preparations in that untreated animals never survive more than 35 hours (with an average survival time of about 12 hours). They are all the more interesting when it is realized that blood transfusions will not by themselves save these animals. It is hoped that these preparations will be useful in attacking some of the problems raised by the observation and study of the wounded in the field. The current studies on this preparation will not be reported

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

at this time, since what I really intend to add to this conference is not what happens as a result of wounding, but what happens *during* wounding. A concept of the wound mechanics is essential for the interpretation of the pathophysiology and an evaluation of any therapeutic procedures. Fortunately, many of these biophysical events have been defined for us by use of spark shadow-graphs, microsecond x-rays and high-speed motion pictures.

The first principle to be understood is that in order for a wound to be produced it is necessary for a missile to have a minimum striking velocity, this depending both on the character of the missile and the character of the tissue. The first major event occurring during wounding is shown by figure 1, which is a spark shadow-graph showing a small missile striking an air-water interface from above. This shows the hydraulic shock wave which is an extremely high-pressure front that spreads out radially with the speed of sound in water (4,800 ft./sec.) from the point of impact of the missile. This is a physical entity and must not be confused with the physiologic syndrome of shock which might occur subsequently. It is currently believed that the shock wave causes no tissue damage except perhaps in the presence of a gas-filled viscus.

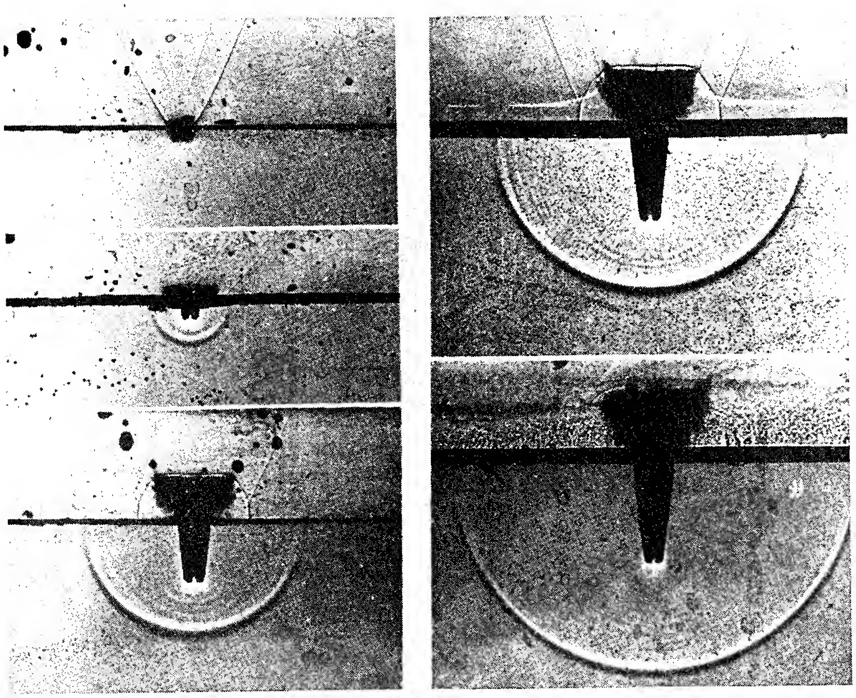

FIGURE 1.

SOURCE: Harvey, E. N., McMillen, J. H., *et al.:* Surgery *21:* 218–239, 1947.

The second and more important event is the development of a temporary cavity which forms behind the missile, beginning first as a cone-shaped space which can be seen as the black area in figure 1, but which is better illustrated by figure 2, which is a microsecond x-ray of a .45 caliber lead ball that has been fired into a 20 percent gelatin block from above. Twenty percent gelatin is used because it has the same consistency as muscle. It should be noted that it is the presented cross-sectional area of the bullet that forms the cavity and that most of the missile may float free in space never contacting the tissue. As the bullet flings tissue from its path, it imparts energy to it and thus creates secondary missiles out of the body substances. The cone-shaped cavity now becomes cylindrical, producing local forces of the same destructive nature as would have been produced by an actual explosion within the tissue. The displacement is only temporary, however, the tissues tending to snap back roughly into their former position and the cavity pulsating (that is, collapsing and re-expanding) a few times before finally disappearing. Figure 3 is a series of x-rays (exposure time—1 microsecond) taken at a varying number of microseconds after impact, illustrating these events. It also shows that the cavity continues to grow even though the missile

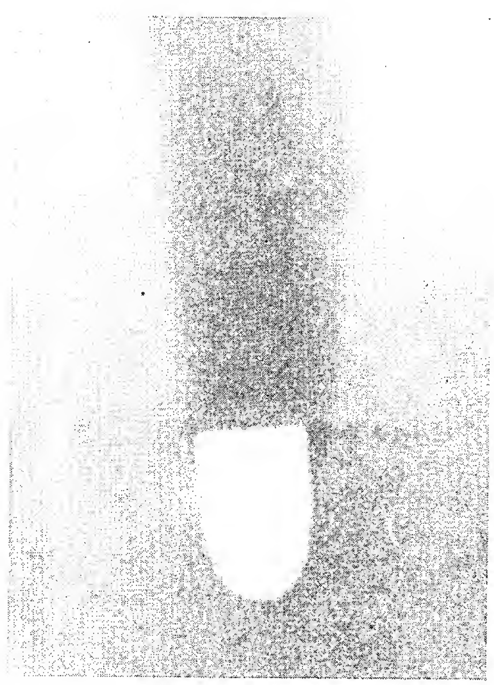

FIGURE 2.

SOURCE: Herget, C. M.: Wound Ballistics in Surgery of Trauma—Ed.: W. F. Bowers. J. B. Lippincott Co., Philadelphia, 1953.

has passed. The cavity concept will seem real, I am sure, if you will refer to figure 4, which is a microsecond flash picture of our high-velocity wound preparation taken 2,000 microseconds after impact of the missile.

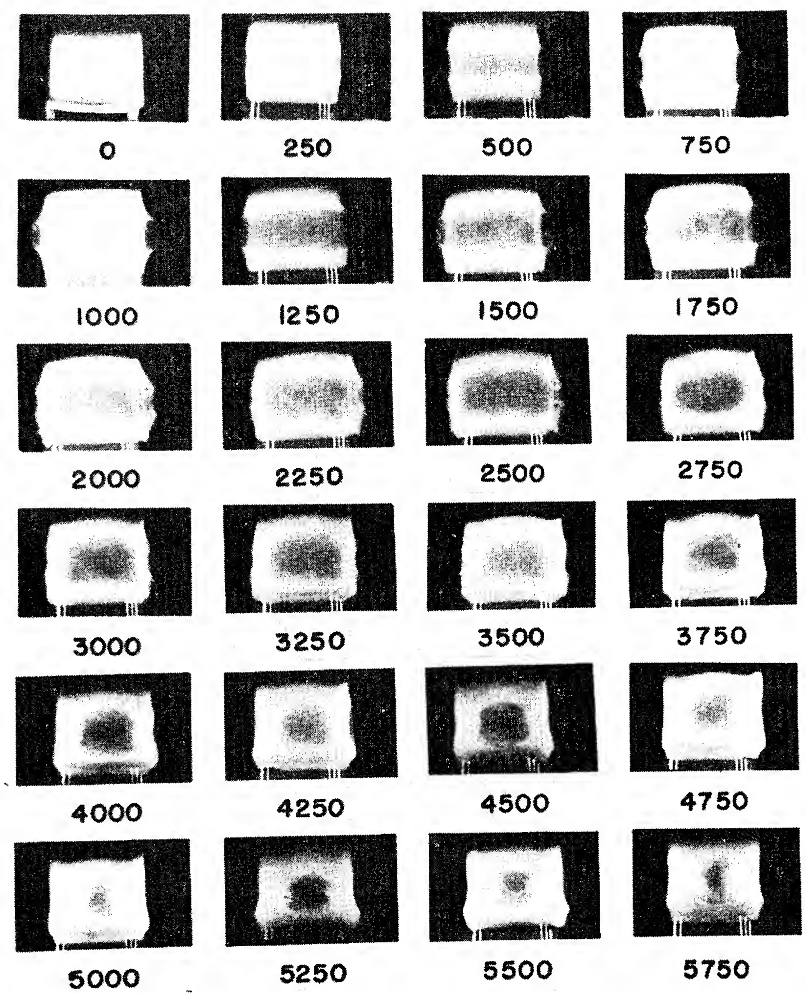

FIGURE 3.

SOURCE: Herget, C. M.: Wound Ballistics in Surgery of Trauma—Ed.: W. F. Bowers. J. B. Lippincott Co., Philadelphia, 1953.

The maximum size of the temporary cavity is a function of the energy transfer and thus the velocity of the missile, the cross-sectional area presnted by the missile, and the elastic properties of the tissue. Figure 5 shows the effect of cross-sectional area for a .30

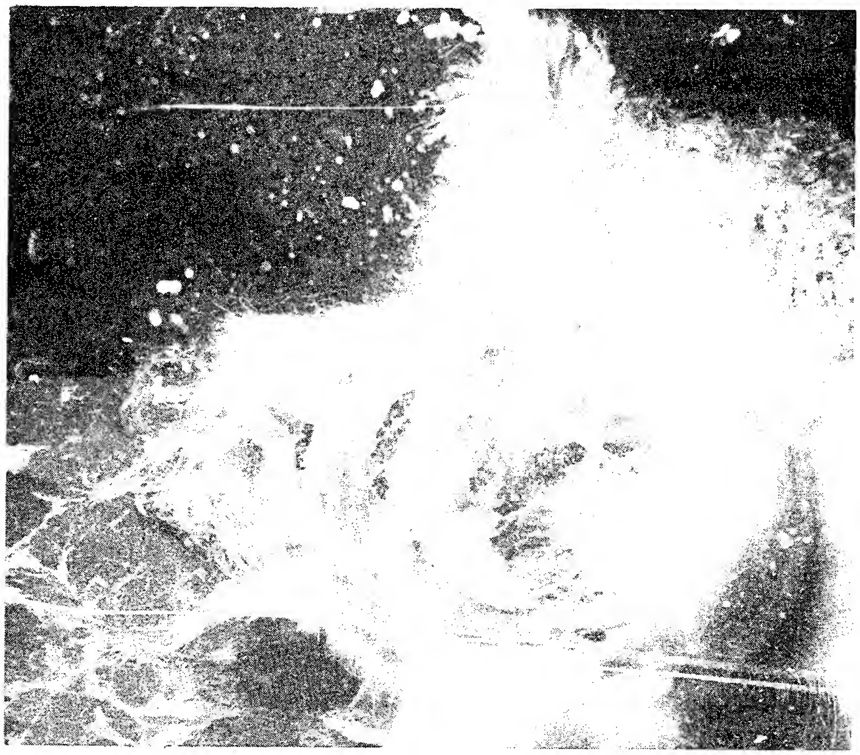

FIGURE 4.

SOURCE: Biophysics Div., Med. Lab., Army Chemical Center, Maryland.

FIGURE 5.

SOURCE: Biophysics Div., Med. Lab., Army Chemical Center, Maryland.

caliber bullet that was fired into a long gelatin block from the right. It began to tumble in the middle and presented its broadside to the left-hand side of the gelatin block.

The phenomena that I have mentioned have all been demonstrated to occur during missile wounding. What happens during wounding with a high explosive is less understood. It is known, of course, that one starts out with a solid material and ends up with a gas. The actual process of disintegration and the biophysical changes produced during this process need further elucidation. It is believed, however, that the same basic phenomena occur as in missile wounding. That is, there is the shock wave to begin with, and then the cavitational effect, perhaps myriads of cavities are produced as the solid charge bursts into small burning particles which enter the body as individual missiles until they burn up.

It should be easy to appreciate that the final wound seen by the surgeon may not reveal the total amount of tissue damage incurred at the time of wounding. After all, the permanent wound cavity represents only that tissue which has been permanently excavated or exteriorized. This can be demonstrated by figure 6, which shows the large radiolucent temporary cavity and the permanent cavity which is injected with radio-opaque material. It takes little imagination to appreciate that there is considerable tearing and crushing of tissues at a far distance from the permanent wound cavity.

In fact, in our standard wound preparations I have been impressed by the amount of damage done to vessels, nerves, and even bones (note the femur in figure 6)—although not directly hit by the missile. In the case of muscles, it appears that for many inches from the permanent wound, there may be damage in those portions of the muscle adjacent to the fascia, although the rest of the muscle appears normal. This suggests, as might be expected, that the temporary cavity spreads largely along the fascial planes, and it emphasizes the desirability of opening the fascia in the surgical treatment of these wounds.

As a result of the temporary cavity we can expect that not only destruction but contamination will be found far from the clinically presenting wound. In fact, Dziemian (1) has demonstrated that during the tension phase of the temporary cavity foreign material is actually sucked into the wound and not carried in by the missile. It must also be realized (fig. 7) that in the presence of armor, damage can be done by the temporary cavity even though the missile has been completely defeated. Proper offset of the body armor will, of course, eliminate much of this danger, but while saving wounds armor may introduce occult wounds and other problems for the field surgeon.

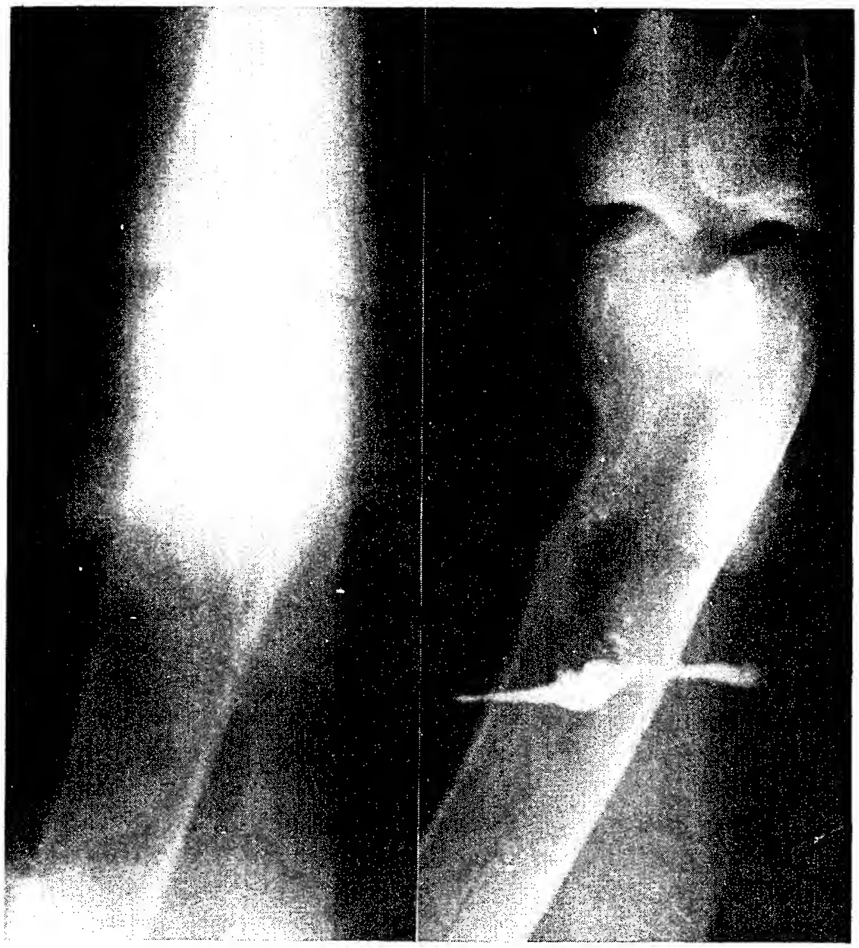

FIGURE 6.

SOURCE: Herget, C. M.: Wound Ballistics in Surgery of Trauma—Ed.: W. F. Bowers. J. B. Lippincott Co., Philadelphia, 1953.

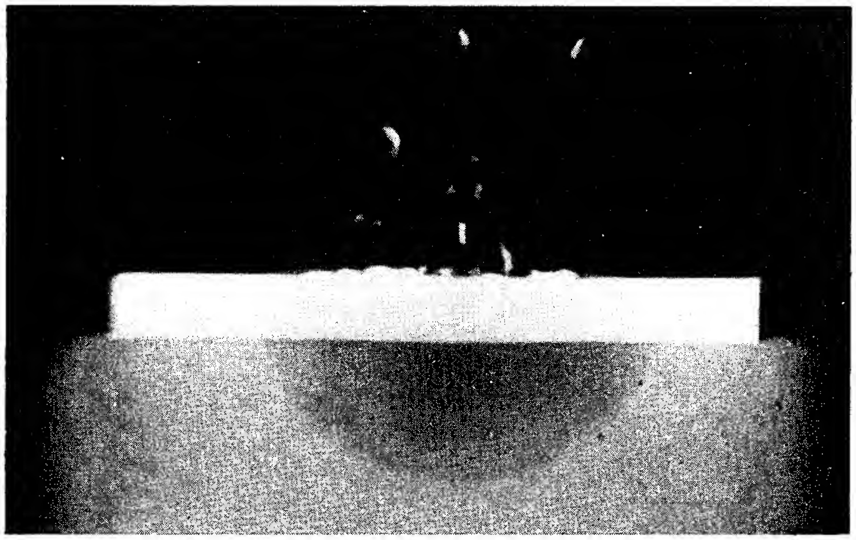

FIGURE 7.

SOURCE: Herget, C. M.: Wound Ballistics in Surgery of Trauma—Ed.: W. F. Bowers. J. B. Lippincott Co., Philadelphia, 1953.

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PREOPERATIVE AND POSTOPERATIVE CARE OF BATTLE CASUALTIES*

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AND

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In recent years, more and more attention has been focused on the care of patients before and after operation. In the Korean conflict, great emphasis was placed on preoperative and postoperative care.

General Aspects of Preoperative Care

As soon as a casualty is admitted to the hospital all his clothing should be removed. In the preoperative section, it is important for the medical officer to examine the entire body in order that all wounds may be recognized. A brief record should be made of the findings. A review of the emergency medical tag will point out the results of previous examinations. It may be necessary to perform a very cursory examination and immediately begin restorative treatment. A more complete examination can be carried out when the casualty's general condition improves.

A record of the blood pressure and pulse rate should be started immediately upon admission. This record may be maintained by the attending corpsman. It provides the medical officer with information concerning the progress of the injured soldier's condition.

Most wounded men require resuscitative fluids. Replacement therapy should be instituted in accordance with the severity of the injury. Large-bore needles should always be used for infusion. It may be necessary to expose a vein surgically and insert a cannula or to insert a long, polyethylene catheter through a large-bore needle into the femoral vein. Since wounded men are usually restless, the needle or cannula must be fastened securely.

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Adequate Airway

Casualties with injuries of the chest, neck or head may have obstructions of the respiratory passages. An adequate airway must be established as soon as possible. This may be accomplished by aspirating the posterior pharynx and trachea and positioning the casualty on his side and pulling out his tongue. Not infrequently a tracheotomy will be necessary. Tracheotomy should never be delayed or considered as a last-resort measure. It is a simple operative procedure that not only assists in establishing a clear airway but offers a convenient and safe method of maintaining tracheobronchial toilet. Increased secretions or blood in the trachea may lead to anoxia. Oral or nasopharyngeal suction consume time and may be inadequate. After a tracheotomy is performed, it is easy for the corpsman or the nurse to keep the trachea clear. Too frequently tracheotomy is delayed because it is believed to be a procedure that increases nursing care; actually, however, it lessens nursing care.

Control of Hemorrhage

Careful attention should be paid to control of hemorrhage. In the most severely wounded casualties, it may be quite difficult. In the slightly wounded casualty, hemorrhage can usually be controlled by a pressure dressing; however, all areas of injury should be observed and adequate dressings should be applied. Too frequently several small wounds will be neglected and an appreciable amount of blood will ooze from them. In the preoperative section of a forward hospital, careful attention should be paid to the proper application of tourniquets. Patients may be observed who actually have an increase in the amount of blood lost from a limb because of the application of a tourniquet. A tourniquet will control bleeding in most casualties who have wounds of an extremity. Sometimes a tourniquet partially controls arterial bleeding, but actually increases venous oozing. It is necessary to apply a firm, bulky pressure dressing in order to control venous bleeding. In casualties with laceration of a large vessel, hemostatic clamps may be applied if the vessel can be easily located.

Narcotics

Severely wounded soldiers experience little pain but have a great deal of fear and anxiety. It is important that the medical officer, nurse and corpsman attempt to alleviate this fear and anxiety. The patient should be made as comfortable as possible. Such a simple procedure as washing a patient's face may help considerably in contributing to his feeling of well-being. It may be necessary to give some patients a narcotic. For an immediate effect, it should be administered intravenously.

RECENT ADVANCES IN MEDICINE AND SURGERY

Prevention of Infection

American soldiers are immunized with tetanus toxoid. A booster dose of toxoid should be given as soon as a casualty is admitted to a forward hospital. Antibiotics should be given to all wounded soldiers to prevent infection. The amount and type of antibiotic therapy may vary according to current practice. At the 46th Surgical Hospital, casualties were given 500,000 units of penicillin and 0.5 gram of streptomycin intravenously as soon as they were admitted. Intravenous antibiotic therapy was continued throughout the early postoperative course. As soon as the injured man's condition was stabilized, 600,000 units of crystalline penicillin and 0.5 gram of streptomycin were given intramuscularly twice a day for the first 5 days. Thereafter, antibiotic therapy was given only on specific indication. In abdominal injuries, some surgeons used 1 gram of terramycin intravenously twice a day.

Abdominal Wounds

An indwelling gastric tube should be placed in all casualties who have abdominal injuries. An attempt should be made to empty the stomach. This is frequently unsuccessful because of the presence of a large amount of undigested food in the stomach at the time of injury.

By placing a catheter in the bladder, output of urine can be measured and information can be obtained concerning injury to the genitourinary tract. If there has been damage to the urinary system, the urine will show gross blood. The rate of flow of urine will indicate the adequacy of resuscitation.

Whenever a wound of the rectum is suspected, a rectal examination should be made. If injury cannot be determined by digital examination, a proctoscopic examination should be performed. Most surgeons insert the proctoscope on the operating table immediately after the induction of anesthesia.

Roentgenograms are of value in determining the presence of shell fragments, free air or retroperitoneal hemorrhage. It is difficult to localize fragments in the abdomen accurately, especially if they lie near the spine, in the pelvis, or near the parietal peritoneum. Free air under the diaphragm indicates a perforated viscus, and absence of a psoas shadow usually denotes obliteration by hemorrhage.

In the preoperative preparation of casualties with abdominal injuries, it is important to determine immediately the presence of gross intra-abdominal hemorrhage. If a wounded man does not respond readily to a rapid infusion of blood and if he has a rapidly expanding abdomen, it may be assumed that a large abdominal vessel has been injured. In such instances, blood should be infused rapidly and

immediate operation should be performed without further preparation.

The surgeon who is to accept the responsibility of operation should go over the casualty's entire history, record of examination and x-rays. Not infrequently certain injuries are missed by the operating surgeon unless he makes a thorough review of the findings. The surgeon should discuss the proposed operative procedure and resuscitative measures with the anesthesiologist.

Immediately after operation, an accurate chart should be kept of blood pressure, pulse rate and hourly output of urine. This will indicate the progress of the casualty and aid in determining the amount of resuscitative fluids required. A hematocrit may be of some value in determining the need for further blood. A hypotensive casualty with a low hematocrit usually requires additional blood. However, most soldiers who have abdominal injuries have a hematocrit that may rise for the first 24 or 48 hours after operation. This is believed to be caused by loss of plasma into the lumen of the bowel, into the bowel wall and into the peritoneal cavity.

Intragastric suction should be continued. A great deal of care may be required to keep the tube functioning. Frequent irrigation of the tube is essential. In casualties with an intranasal gastric tube who are also receiving oxygen by nasal catheter, it is important to be certain that the oxygen cylinder is not inadvertently connected to the gastric tube. When this occurs, tremendous gastric dilation follows and the casualty's condition may deteriorate rapidly. Acute gastric distention may occur in the presence of a non-functioning intragastric tube when oxygen is administered by nasal catheter.

In the immediate postoperative period, frequent examination of the casualty should be made. Since atelectasis is one of the more common complications following abdominal injuries, the patient should be urged to take deep breaths and to cough. A good method of maintaining tracheal toilet is aspiration of the trachea through the nasopharynx at frequent intervals. When heavy, thick secretions block the bronchial tract, bronchoscopy may be necessary.

As soon as the blood volume has been restored, electrolyte solutions and water should be given. Most casualties have been without water for many hours. Some of these soldiers may have been on patrol prior to injury. Casualties who have abdominal wounds require at least 3,000 cc. of fluids by vein daily; 1,000 cc. or more of glucose in saline and 2,000 cc. of glucose in water. When intragastric suction is continued for several days, the casualty may require potassium.

Most young soldiers who sustain abdominal wounds can be ambulated on the day following the operation. On the second or third postoperative day, an abdominal wound should be examined. The

wire stay sutures may require loosening because of edema of the wound edges. Before a casualty is evacuated, a careful examination should be made of all his wounds.

Thoracic Wounds

Many thoracic wounds do not require operation and are therefore treated in the preoperative section of the hospital. Hemothorax or pneumothorax should be diagnosed as early as possible and can usually be managed by thoracentesis. Tension pneumothorax requires immediate decompression. If a wounded soldier has an injury to the chest and if he has a great deal of respiratory difficulty, it is unnecessary to wait for roentgenograms. Exploratory thoracentesis may be carried out to aspirate air or blood. Sucking wounds of the chest should be closed by a large occlusion dressing. In preoperative preparation of a casualty with a thoracic injury, it is the surgeon's aim to restore the respiratory physiology as nearly as possible to normal. This may require a tracheotomy in order to clear the respiratory tract of excessive secretions and blood. An intercostal nerve block relieves pain and permits increase in respiratory excursion.

In casualties that require multiple, frequent thoracenteses, a tube thoracotomy may be performed. When a tube is inserted and water-seal drainage is used, particular attention must be paid to the mechanics of the system in order that water will not flow into the pleural space. The tube should be removed before the casualty is evacuated. In the Korean conflict, several wounded soldiers were evacuated with tube thoracotomies in place and subsequently empyema developed.

Repeated roentgenograms may be necessary in order to follow the course of the pulmonary changes. Thoracotomies should be drained postoperatively with water-seal drainage in nearly all patients. The water trap bottle should be clearly labeled and corpsmen should be instructed to pay particular attention to the apparatus.

Since atelectasis is a frequent complication of chest operations, every effort should be made to encourage the patient to breathe deeply and to cough frequently. Intercostal nerve block helps the patient to breathe more comfortably and to cough. Whenever atelectasis occurs, a bronchoscopy should be performed.

Care should be taken not to overtransfuse casualties who have sustained injuries to the chest. Frequent auscultation is required to evaluate the chest findings.

A roentgenogram should be taken immediately following a chest operation and at regular intervals thereafter. Narcotics should be used sparingly. Most pain can be controlled by intercostal nerve block.

TUESDAY AFTERNOON SESSION

Extremity Wounds

In wounds of the extremities, careful records should be made of nerve, vascular and bone injury. It may be necessary to refer to these findings later.

When a fracture is present, the extremity must be immobilized. Motion in an unsplinted extremity causes considerable pain, further tissue damage and bleeding. Roentgenograms should be made in all extremity wounds in order to determine the site and extent of bone injury and the location and size of retained fragments. When several wounds have been débrided and left open, considerable oozing may occur. Postoperatively, frequent examinations of wounds should be made in order to detect any further bleeding. The extremity enclosed in a cast should be examined for edema and evidence of circulatory impairment. Although all casts have a segment resected to permit expansion when edema occurs, the surgeon must make sure that undue pressure is not being exerted on any part of the injured extremity.

In extremity wounds, it is extremely important to explain the extent of injury to the casualty. In many instances, an injured soldier is fearful that his injury may lead to amputation or permanent disability. In casualties on whom amputations have been performed, great care must be taken to explain that every effort was made to save the extremity. A soldier will usually accept this new situation better if an explanation is made at the forward hospital, rather than later. Chaplains and nurses are of assistance to the surgeon in helping an injured soldier overcome his problems of adjustment.

Casualties who have minor wounds of the extremities may be evacuated on the day following injury. When casualties are held longer than 24 hours, however, wounds should be examined and redressed prior to evacuation. This gives the surgeon an opportunity to determine the adequacy of the débridement and to make sure that the wounds are properly dressed before evacuation. It is difficult to do a complete débridement in very large wounds of the buttocks and upper thigh; hence further excision of devitalized tissue is usually necessary. This should be carried out before the casualty is evacuated.

Wounds of the Neck and Face

The usual preoperative procedures of blood replacement and roentgenographic examination are carried out in casualties who have wounds of the neck. If profuse bleeding occurs inside the mouth, it may be necessary to do a tracheotomy and pack the mouth in order to control hemorrhage. In wounds of the neck, a tracheotomy may be

required for the establishment of an airway or for tracheobronchial toilet.

Improvement of Preoperative and Postoperative Care

In any type of medical care, it is important to maintain a record of experiences. Only by reviewing casualties' records can information be ascertained about the mortality, morbidity, complications and efficacy of treatment. Since evacuation, tactical situations and types of injury differ from war to war—even from campaign to campaign—it is imperative in forward surgical units to keep careful records and analyze them frequently.

Routine records are necessarily brief because of time limitations. These records are usually placed in an envelope and they accompany the casualty as he is evacuated. Unless a separate record is kept at the forward hospital, the medical officers in forward units do not have an opportunity to review their experiences. To depend upon each surgeon to maintain a record of his own experiences will not provide uniform data. Therefore, it is necessary to furnish some type of standardized data sheet for use in forward areas. The data from these sheets should be thoroughly studied each month in order that the medical officers may obtain a summary of their experiences and be guided accordingly if changes in technics and practices are indicated. Unless some satisfactory procedure is established for summarizing current experiences, it is difficult to determine the problems that require further study and to ascertain the areas in which improvements must be made.

During the final few months of the Korean conflict, a statistical data sheet was used at the 46th Surgical Hospital. This form was placed in the wounded soldier's envelope and accompanied him through the preoperative section, operating room and recovery section. The initial information on resuscitative fluids and time intervals was completed during the operative procedure by the anesthesiologist. The remainder of the sheet was completed by the surgeon. These sheets were retained at the hospital and summarized monthly. All surgeons then had an opportunity to observe the results of their work.

A tremendous amount of valuable information might be gained in a theater of combat if these data sheets were completed on every casualty seen in a forward surgical hospital. At the end of each month, summaries of the information on these forms could be sent to the surgical consultant in the theater, and he, in turn, could correlate the information and obtain an overall view of the professional care being administered throughout the theater. Without some type of statistical summary it is impossible to obtain the much needed information on surgical experiences and care.

DISCUSSION ON CONSULTANTS AND ORGANIZATION OF SURGICAL SERVICE*

MAJOR CURTIS P. ARTZ, MC

Various types of organization have been used on surgical services in forward units. Auxiliary surgical teams were utilized in World War II. The organization and working schedule should be made for greatest efficiency. Usually it is wise to divide the surgeons into two groups in order that each group may be responsible for a 12-hour period—one team for daytime surgery, the other for night surgery. The teams may shift from week to week in order that one group may be on duty during the day for one week, then during the night the following week. It is of greatest importance that each team have as a team captain a more experienced surgeon who is responsible for all patients admitted during his team's period of duty.

The chief of surgery should supervise and be responsible for all patients admitted, regardless of the team that is on call. Since he cannot supervise the preoperative, operative and postoperative phases of every patient's care, he should have as deputies two skilled surgeons who have had appreciable experience in the management of battle casualties. These captains of the surgical teams may then designate the operator for each particular case and assist the less experienced men with preoperative preparation, operation and postoperative care. Unless this type of plan is followed, surgeons with inadequate experience may be forced to handle severe cases that should be cared for only by more mature surgeons. Triage in the preoperative section is an important function of the captain of the surgical team. The chief of surgery and the team captains should visit the evacuation hospital occasionally to ascertain the results of the initial surgery.

When a new surgeon first arrives at a forward surgical unit, he must be carefully indoctrinated in the surgery of the severely wounded. The organization of a forward surgical service should be somewhat similar to the organization of a department of surgery in civilian medical schools. The chief of surgery serves as the professor and his two assistants are responsible for their two separate services. The surgeons who head the services have less experienced men on their

*Presented 20 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

staff for whom they are responsible. Only with an organization of this type can the training and experience of the surgeons be utilized in the most efficient manner. It is most unfair to the severely wounded soldier to permit a less experienced surgeon to care for him when the judgment of a more experienced surgeon is available.

During times when casualty loads are heavy, it is imperative that surgeons be given adequate time for rest. Usually a 12-hour schedule is optimum. On the other hand, if 8 hours are available for much needed rest, it has been found possible for a surgeon to be on duty during a 16-hour period. Adherence to a rigid schedule is most important, with definite periods of rest during times of increased activity.

Because of the type of injury and the limited number of surgeons, many operative procedures are performed without an assisting surgeon. Surgeons soon become accustomed to operating with one or two capable technicians. They must select the patients on whom they require another surgeon as first assistant. This is usually necessary in most abdominal wounds and chest wounds. Minor débridements may be done with the aid of one scrub technician. However, when a large amount of muscle is damaged and there is profuse bleeding, it is important that a capable assistant be available in order that the operation can be conducted with maximum hemostasis in the shortest possible time. All too frequently, inadequate assistance leads to unwarranted blood loss.

When multiple areas are involved, it is wise to use two surgical teams on the same patient. One team may perform an upper extremity amputation as another team débrides or amputates a lower extremity. The utilization of two teams decreases the time under anesthesia and proves most beneficial to the patient.

Since initial surgery in the severely wounded is so important, it would seem wise that the chief of surgery in a forward hospital be a more experienced Regular Army surgeon trained in the principles of resuscitation and combat surgery. So frequently the more mature, higher-ranking surgeons of the Army Medical Corps are assigned to rear hospitals. Because most of the surgeons in a forward hospital are obtained from civilian life and do not have extensive experience in the surgery of trauma, it would seem to be a good policy to have as a leader one of the more mature Army surgeons with previous combat experience. Only by utilizing surgeons with wider knowledge of initial care of the severely wounded man can we expect to decrease the morbitity and mortality of the injured man. *Improved medical care will come with increased emphasis on teaching the principles of forward surgery that are now known. The greatest need in the forward hospitals is dissemination of existing knowledge about resuscitation and combat surgery.* One of the real responsibilities of the Regular

Army surgeon is the care of the soldier wounded in combat. All surgeons in the Regular Army should be thoroughly trained in the management of the problems of trauma. Their subspecialty should be forward surgery. Physicians in civilian life do not have the opportunity to obtain knowledge and experience in the management of severely wounded patients. The problems associated with severe war injuries are peculiar to the Army Medical Corps and its surgeons should maintain a particular interest in this type of management. Young career surgeons in the Regular Army should always be given an opportunity to gain experience in forward surgical hospitals.

Utilization of Consultants

From time to time it is important that experienced, mature leaders in the field of surgery visit forward surgical installations as consultants. Their valuable advice is most stimulating to younger men who are managing battle casualties. The teaching done by these experts is invaluable. Too frequently, however, the consultant visits the rear hospital, the evacuation hospital and several forward hospitals in a short period of time. This permits him to spend only 1 or 2 days at each installation. His knowledge could be better utilized if he actually performed some surgery and, by first-hand experience, became extremely familiar with the problems of the particular institution he visited. A consultant should probably visit only three hospitals; and he might spend 2 weeks at each installation. During his visit he should care for some of the patients, assist surgeons, make regular ward rounds and share his knowledge with less experienced surgeons. The system used by many medical schools of having so-called "visiting professors" for a period of 10 days or 2 weeks is a good one. Such a program could be utilized with great efficiency in a theater of combat. "Visiting professors" in anesthesiology and surgery would lead to a closer bond between military and civilian surgery. As our nation becomes more frequently involved in conflict, it appears that our professors of surgery must stress the principles and concepts of forward surgical care.

WEDNESDAY MORNING SESSION

21 April 1954

MODERATOR

Major William H. Meroney, MC

HEMORRHAGE*

Lieutenant Colonel Carl W. Hughes, MC

It would be presumptuous of me to discuss with this group the classification of hemorrhage and methods of control, but in order to present a number of the observations made in Korea, some of the basic teachings relative to hemorrhage will be mentioned. The conclusions reached here are drawn from observations made at the surgical hospital level.

Hemorrhage by definition is loss of blood from a blood vessel and, as such, is a major contributing factor to shock. Hemorrhage may be classified as primary or secondary and may occur from a lacerated or severed vessel. It may be external or internal, arterial or venous, or both.

Primary

The majority of hemorrhagic problems reaching the surgical hospital were in those patients with wounds of major vessels of one or more of the extremities and wounds of lesser vessels of the abdominal and thoracic viscera. Often, extremity wounds were multiple and complicated by abdominal or thoracic hemorrhage. Most of those patients with wounds of the great vessels of the thoracic and abdominal cavities bled to death before reaching the hospital.

External. Although wounds of major vessels of the extremities were usually accessible to control by tourniquet, observations made from a group of 75 patients with 79 injuries to major vessels of the extremity showed that 47 percent of this group were admitted with a tourniquet in place and 40 percent were in shock. This percentage of patients in shock is indicative of the seriousness of hemorrhage from a major vessel even when in a location where it can be controlled.

Since the severed artery tends to contract, retract and form a clot, it was interesting to speculate whether or not shock might be less prevalent in the patient with a completely severed artery than in the patient with a lacerated or partially severed artery, which is held apart and continues to hemorrhage. Observation of 202 patients with extremity wounds involving major vessels showed that 113, or 56

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percent, had a lacerated artery and 89, or 44 percent, had a severed artery. Using data from only a limited number (32) of this group arriving in shock, an attempt was made to correlate the occurrence of shock with a specific type of arterial injury. Of those studied in shock, it was found that 53 percent had laceration of the artery and 47 percent had a severed artery, showing that shock occurred in the patient with a severed major artery about as readily as in the patient with a lacerated major artery. Although several of these patients had multiple injuries, the gross hemorrhage was from the major vessel involved.

While in general, primary, gross hemorrhage was the immediate problem, continued ooze also proved to be a problem in many instances. Artz, Sako and Howard at the 46th Surgical Hospital (*1*) reported 20 deaths among 138 severely injured patients requiring 5 or more pints of blood each. Of these 20 deaths, 7 died of uncontrolled hemorrhage, 4 from uncontrolled postoperative oozing, and 3 from uncontrolled major vessel hemorrhage.

We have also observed patients continue to ooze and die postoperatively from massive muscle wounds, liver wounds and pelvic wounds. Such continued oozing was particularly evident following multiple transfusions. Dextran was administered alone to some patients and to others in ratios of 1 : 1 of blood and 1 : 2 of blood until some received a total of 2,500 to 3,000 cc. of dextran. No increased bleeding was attributed to use of the dextran, although such has been reported since the war.

Internal. While most primary hemorrhage is external and is obvious or visible hemorrhage, internal hemorrhage is often the more serious problem especially if in the abdomen or chest. Although we usually think of internal hemorrhage as abdominal or thoracic, it often occurs in the presence of comminuted fractures, especially fractures of the femur. Following such hemorrhage, a patient may show signs of severe shock without evidence of external bleeding. Another hidden form of internal hemorrhage is the pulsating hematoma. Following injury to an artery, the blood may be retained between fascial and muscle planes or in the soft tissue forming a pulsating hematoma. The center of the hematoma communicates with the hole in the artery and contains liquid blood while the peripheral portion of the hematoma tends to laminate and clot, forming a false sac, the beginning of a false aneurysm. If both artery and vein are injured and the clot is contained in a similar manner, then an arteriovenous fistula is likely to develop.

Blood flow distal to such pulsating hematomas will vary depending on the severity of the injury to the artery, the number of collaterals destroyed, the size of the hematoma, the pressure exerted by the hema-

toma, and the peripheral resistance. When the extremity distal to the site of vascular damage has ample blood supply and the hematoma is self-contained and uninfected, it may be expedient to allow the pulsating hematoma to develop an arteriovenous fistula or false aneurysm which may be operated on at a later date. This is particularly true of carotid and high subclavian artery injuries. Surgery for a pulsating hematoma in either of these locations may result in profuse hemorrhage before control can be obtained. Clamping of the damaged carotid artery for only the length of time required to repair it may lead to a fatality at this time.

Secondary

While the pulsating hematoma of arterial origin is more likely to expand and cause pressure on adjacent structures, both the arterial and the arteriovenous types of pulsating hematomas may bleed secondarily, especially in the presence of infection.

Secondary hemorrhage is usually arterial and may occur from a slipped ligature, from the faulty suture line of a repaired vessel, from slough of an injured vessel, or an overlooked vessel injury that has previously thrombosed. Infection predisposes to secondary hemorrhage. Such hemorrhage may occur from a severed or lacerated vessel as infection liquefies the clot. This is particularly true in the presence of pulsating hematomas. Russell (*2*) reported 59 cases of secondary hemorrhage developing at Tokyo Army Hospital in patients evacuated from Korea. He found that most secondary hemorrhage from war wounds occurred between the eighth and eighteenth days after wounding but varied from 5 to 44 days.

Control

A study of 79 major vascular injuries in extremities showed that 47 percent were admitted with a tourniquet in place which had been applied from 40 minutes to 14½ hours previously, the average time being 4 hours. Tourniquets were found applied, covered by dressings and forgotten. Sometimes the presence of a tourniquet or the time of application was not noted on the field medical tag. Some tourniquets had cut deeply into the soft tissues. Others were applied at levels which required amputation of an extremity higher than was necessary for the injury alone.

It is believed that a tourniquet should be applied only tight enough to control hemorrhage and left in place until it can be removed by a medical officer with blood or plasma expander available to resuscitate the patient. When packs or pressure dressings will suffice, the tourniquet should be removed and the pressure dressing applied only tight enough to control the hemorrhage. Dressing can be carelessly applied

as tightly as a tourniquet. If applied properly, packs and pressure dressings will often control the major hemorrhage and allow some collateral vessels to function. Patients with pressure dressings must be observed carefully to make sure that bleeding does not recur as the blood pressure increases with resuscitation.

Now that the repair of acute vascular injuries is feasible, every effort should be taken to repair the damaged artery. Some patients with major artery injury will have hemorrhaged so severely that resuscitation becomes a major problem requiring prolonged use of a tourniquet. Continued use of the tourniquet during prolonged resuscitation may result in a nonviable extremity. In such cases with open wounds it may be practicable to clamp the injured artery as near the damaged site as possible preserving as much of the artery as possible for repair. In this manner, the remaining collateral vessels are free to function while resuscitation is being accomplished. This procedure is not without danger. If the tourniquet is removed during a critical stage of resuscitation, even after control of the damaged vessel, tourniquet shock may occur. If clamps are to be utilized to control the hemorrhage, they should be applied at the beginning of resuscitation, or when bleeding cannot be controlled by a tourniquet, or after the blood pressure is stabilized and it is evident there will be a prolonged delay before surgery.

Care must be taken to avoid tourniquet shock when loosening or removing tourniquets that have been in place for a number of hours. We observed, as an example, a patient admitted in profound shock with both legs mangled and with tourniquets high on his thighs. He received 19 pints of blood before a thin pulse became palpable. After receiving 5 more pints of blood and dextran, he developed a near normal blood pressure. Since his tourniquets had been in place for 6 hours it was decided to loosen them slowly and replace them distally in hopes of salvaging the knee joints. While this was done without any evidence of external hemorrhage, the patient's blood pressure dropped again and in spite of 4 more pints of blood given rapidly, the patient died, having received a total of 28 pints of blood.

Tourniquets should normally be applied as low as practicable to control hemorrhage but for traumatic amputations the tourniquet should be applied as low as possible on the stump, then it may be left in place indefinitely.

It may be well to mention here the availability of the artery for transfusion in traumatic amputations. Usually such patients have hemorrhaged severely and are in profound shock. Since the artery is a tough, elastic structure it can usually be easily identified in the mangled remains of the extremity. The exposed artery can be

clamped, a large cannula or needle quickly inserted and the blood administered rapidly by the route through which it was lost.

In spite of availability of blood and plasma expanders, hemorrhage proved to be a problem in many instances. Artz, Sako and Howard (*1*) reported 89 severely wounded patients who required 15 or more pints of blood or plasma expander. Sixteen of the patients, or 18 percent, died of continued hemorrhage, most of them with abdominal injury (table 1). The patient with intra-abdominal hemorrhage often cannot be resuscitated preoperatively and has to be taken to surgery for control of hemorrhage.

Table 1. Mortality of Casualties Requiring 15 or More Pints of Blood From the 46th Surgical Hospital

Injury	Number	Died	Mortality (percent)	Number dying of continued hemorrhage
Abdomen	24	19	79	11 (46 percent)
Abdomen and extremities	29	12	41	3 (10 percent)
Extremities	29	5	17	1 (3 percent)
Chest	7	3	43	1 (14 percent)
Total	89	39	44	16 (18 percent)

In order to control intra-abdominal hemorrhage in these patients whose shock could not be controlled by replacement of blood, a balloon catheter was tested as an intra-aortic tamponade in two critically wounded patients. It was arbitrarily decided that the catheter would be used only in moribund patients with intra-abdominal bleeding in which blood pressure could not be obtained after administration of 10 pints of blood. The catheter was utilized by inserting it through the femoral artery to the level of the diaphragm, then inflating the balloon with 20 cc. of sterile saline. The catheter was utilized in two moribund patients.

Case I. The first patient was admitted 1 hour after injury with grenade wounds of the abdomen, thighs, leg and foot and a compound comminuted fracture of the right tibia and fibula. He had received 1,000 cc. of plasma prior to admission. On admission, his pressure was 40 systolic with a questionable diastolic level and pulse rate was 120. There was abdominal distention suggesting uncontrolled intra-abdominal bleeding. In the receiving ward he was given 2,000 cc. of whole blood and 500 cc. of dextran, and his blood pressure was read as 58 systolic with questionable diastolic pressure and pulse 120. He received 2,500 cc. more of blood without improvement. He was then taken to surgery in a moribund condition. There, no blood pressure

could be obtained. The catheter was inserted and passed to the level of the diaphragm, where the balloon was inflated. The abdomen was then quickly opened and 1,500 to 2,000 cc. of free blood was aspirated. A bleeding external iliac vein was controlled and a massive laceration of the right lobe of the liver was packed and sutured.

After 15 minutes the catheter was slowly deflated, moved down to the bifurcation of the aorta, and reinflated to allow oxygenation of the kidneys, liver and spinal cord. This permitted multiple bleeding points in the bowel and mesentery and around the celiac axis to present themselves. With this bleeding, the blood pressure was again unobtainable and breathing became labored. The catheter was then replaced and inflated at the level of the diaphragm. The pressure was obtained at 78/50; then rose to 100/54, and respiration again improved. While the catheter at the diaphragmatic level controlled the bleeding and maintained a pressure, it also obscured the bleeding points so that they could no longer be found.

After 10 minutes at this level, the balloon was again slowly, partially deflated to expose the bleeding points, but the blood pressure was again lost. Re-inflation of the catheter balloon returned the blood pressure to 96/54, but again obscured the multiple bleeding points.

As the catheter was repeatedly deflated to demonstrate the bleeding points, the blood pressure continued to fall, and the patient's condition gradually became worse until he died on the operating table. It was feared that prolonged use of the high aortic tamponade might result in liver, renal or spinal cord damage from anoxia.

During surgery, the patient received 13 additional pints of whole blood and 1,000 cc. of dextran to total 22 pints of blood and 3 pints of dextran.

At autopsy, no damage to the celiac axis was demonstrated, but in addition to the damaged liver and iliac vein, there were multiple injuries to branches of the splenic artery, the mesenteric arteries, and a severed spermatic artery.

Case II. The catheter was utilized too late in the second patient for a blood pressure response. Although this patient received 24 pints of blood, he died almost simultaneously with insertion of the catheter.

The fear of harming a patient who might have been resuscitated without use of the catheter caused us to reserve it for use in absolutely moribund patients. Possibly these patients would have had a better chance for survival had it been used earlier. Although both patients died, the catheter was effective in temporarily restoring blood pressure in one patient and should be further evaluated experimentally and clinically.

Summary

1. Primary gross hemorrhage was the usual immediate problem encountered in the wounded in Korea but continued ooze also proved to be a problem at times.

2. Secondary hemorrhage played an important role, especially hemorrhages resulting from pulsating hematomas and in the presence of infection. This was particularly observed during the mass evacuation of the early days of the war.

3. The control of hemorrhage is discussed and the dangers of improper use of a tourniquet are discussed.

4. The use of an intra-aortic balloon catheter tamponade as a method of controlling intra-abdominal or intra-thoracic hemorrhage is presented.

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SHOCK

A STUDY OF THE KOREAN BATTLE CASUALTY*

JOHN M. HOWARD, M. D.

To appreciate shock following injury is to appreciate the entire field of trauma: the wounding agents, the nature of the injuries, the body's response to injury, the characteristics of the resuscitative agents, the effectiveness of the resuscitative methods, and the sequelae of injury, for all are entwined in the clinical syndromes found in the wounded soldier. As we learn more about the nature of injury and the body's response to injury, we shall, as so fittingly suggested by Green and Stoner, discard the term shock and speak of the specific injury and the specific resultant deficiency and response. We can almost justify such a step now. The value in retaining such an all-inclusive term is only to focus attention on the serious deficiency of the circulatory system. There is no common cause of hypotension following injury and therefore no common therapy. A wound of the central nervous system may produce hypotension by injury to the sympathetic nervous system. An injury to the heart or pericardium may produce hypotension due to a primary deficiency in cardiac output. An open chest wound may produce hypotension due presumably to a loss of the thoracic pump mechanism and so a decrease in return of blood to the right side of the heart with a resultant decrease in cardiac output. These are specific wounds causing specific deficiencies and requiring specific therapy. To class these patients together under any single diagnosis or plan of therapy will result in added fatalities.

Hypotension and shock are therefore no more specific than fever or jaundice. Like the latter terms, however, they serve to focus attention on the gravity of the situation in the individual patient. Although hypotension may have many causes, the chief factor in most casualties, as was pointed out by the Board for the Study of the Severely Wounded, is a deficiency in blood volume. It is this group of patients with injuries primarily of the abdomen and extremities with whom we are chiefly concerned.

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*Presented 21 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

The present concept of shock, as further developed in our Korean studies, is based on our knowledge of the nature of the injury and the body's response to the injury. Such knowledge may be summarized as follows:

1. The battle wound is dynamic. The battle wound results in a defect which produces a continuing deleterious effect. This continuing deleterious effect must be minimized by operative débridement.
2. Following injury the body responds to correct the defects. This is a continuing response of every organ and system which has been studied. This response may be life-saving.
3. Anesthesia blocks part of the patient's response and therefore, at least for the moment, furthers the injury.

The thoughts expressed grew out of the many informal conversations held around the litters of the wounded at the 46th Surgical Hospital and around the laboratory of the Surgical Research Team in Korea. Many of the expressions are thus not original with the speaker and much of the work mentioned is the work of his colleagues.

With severe injury there is a response of every part of the body to compensate for, and reverse or heal the injury. This compensatory mechanism, like life itself, is an interdependent mechanism, dependent upon the circulation of blood from one capillary bed to another. It is a continuing response. One element of the injury is blood loss. When blood loss is of sufficient degree, an inadequate circulation results. Hypotension is one manifestation. This state of circulatory insufficiency damages the various organs taking part in the compensatory effort. Circulatory insufficiency, produced primarily by blood loss, therefore furthers the injury by destroying the defense mechanism.

Shock might therefore be defined as the clinical picture of an inadequate circulation following trauma. It is due initially to an inadequate circulating blood volume.

What is the background to wound trauma? A massive wound includes the following elements:

1. Tissue destruction.
2. Blood loss.
3. Bacterial contamination.
4. Mechanical defects.

These are the four wounding elements. A fifth which may ultimately prove of importance is the direct transmission of energy from the missile to the entire body, depicted only locally as tissue destruction. A functional aberration, quite distal to the missile, may prove to result from the direct transmission of energy just as with an elec-

trical shock. All of these elements of the wound produce a deleterious effect, the summation of which Churchill has termed wound shock.

Tissue destruction produces a dynamic wound. It is not an injury which occurs for the moment. As Beecher described, it continues to exert its deleterious effect. Blood is lost externally and into the injured areas. Albumin, water and electrolytes are extruded. Products of tissue breakdown are absorbed as are the toxins of bacterial action. Thus there is an exchange of substances by the circulation at the site of the undébrided wound to the net disadvantage of the body (fig. 1).

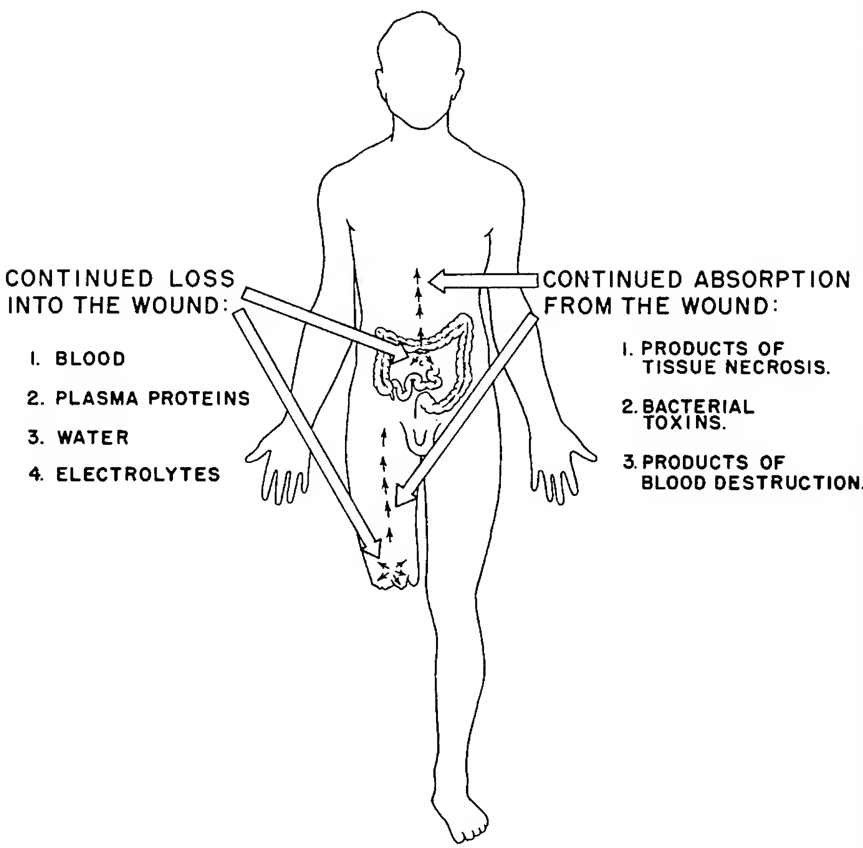

FIGURE 1.

With a severe injury, the body responds *in toto*. Every system, every organ and presumably every cell in the body responds to severe trauma.

Among the responses we recognize are the following; there is much overlap, but the following list indicates a way of thinking:

A. The emotional response of fear.

B. Response to tissue destruction.

1. Pain.
2. Inflammation.
3. "Metabolic débridement" (internal débridement) of the wound.
4. Tissue slough (external (débridement).
5. Wound healing.

C. Response to blood loss.

1. Response of the autonomic nervous system.
2. Adrenal cortical response.
3. Renal vasoconstriction.
4. Increased production of clotting factors.
5. Regeneration of red blood cells and proteins.

D. Response to bacterial contamination.

1. Leukocytic response.
2. Antibody formation.

E. Response to mechanical defects—circulatory and respiratory changes following increased intracranial pressure, respiratory obstruction, cardiac tamponade, sucking chest wound, etc.

F. Paralytic ileus.

These responses are part of the compensatory mechanisms. Most of them are a response to hemorrhage and tissue destruction.

As a result of some of these responses, compensation of the circulation may result, but if the initial trauma is too great, or is repeated, and the resultant blood loss is too great, peripheral vascular inadequacy results. This does not imply a decompensation of the peripheral vascular mechanism. The autonomic system, heart and peripheral vascular bed may be functioning maximally. The injury and blood loss were simply so great that the compensatory mechanism could not maintain an adequate circulation. Hypotension results.

Most of the studies of shock have centered around the loss of blood and certainly this is the heart of the problem. Our studies confirmed the observation of others that with a rapid loss of 25 percent of the blood volume, hypotension develops. Up to this point, the heart and autonomic nervous system, by increased cardiac rate and vasoconstriction, can compensate for the loss to maintain a normal pressure. After the rapid loss of 25 percent (about 1,200 cc.) hypotension develops and after a rapid loss of 40 percent (2,000 cc.) hypotension is profound. Now, as seen at the forward surgical hospital, this hypotension can invariably be reversed before anesthesia if the central nervous system is intact and if hemorrhage can be stopped. In over 4,000 casualties there was no exception to this statement. At an average time of 3.5 hours after injury and before anesthesia, every casualty could have

his blood pressure restored to a normal level provided there was no injury to his central nervous system and provided hemorrhage could be controlled. To repeat, in the resuscitation of 4,000 battle casualties at an average time of 3.5 hours after injury, irreversible shock was not recognized prior to anesthesia provided hemorrhage could be controlled and there was no injury to the central nervous system. Continued hypotension, at this early time was, therefore, the result of continued hemorrhage or inadequate transfusion. Anesthesia blocks part of the compensatory mechanism and may convert the compensated circulatory system to that of a profound shock. Furthermore, after anesthesia, shock may become extremely, even fatally, resistant to transfusion therapy.

The purpose of the circulatory system is to circulate substances from one capillary bed to another—from lungs to limb, from liver to brain, from bowel to liver, to heart, etc. Circulatory failure is, therefore, a failure of capillary circulation. This failure is brought on by a reduction in the circulating blood volume and I emphasize *volume.* If the volume is suddenly reduced 50 percent, circulatory failure is profound with the blood pressure unobtainable (fig. 2). Under these conditions, total volume, plasma volume and red cell mass are each reduced by 50 percent. Death is imminent. Now, if the 2,500 cc. loss is replaced by dextran in such an amount that the total blood volume is restored, the red cell mass remains at the low

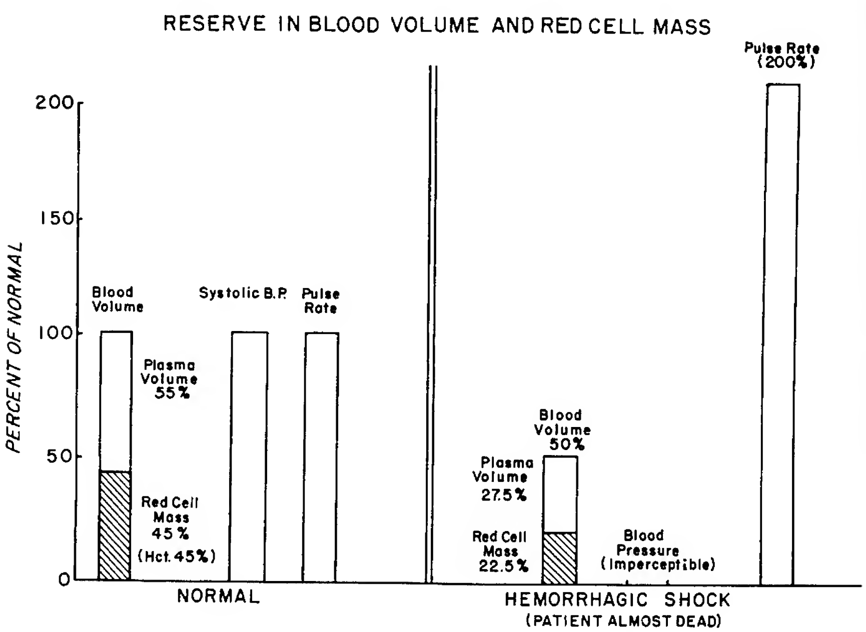

FIGURE 2.

volume of 1,125 cc. so that the hematocrit drops to 22.5 percent. The red cell mass, therefore, has not been changed from that of the severe shock state. Blood volume has been restored, the patient has now responded, his blood pressure is normal, his pulse rate somewhat fast but slower than before therapy, and the man has now compensated (fig. 3). The reserve is therefore far greater in red cell mass percentagewise, than in blood volume. Circulating blood volume and capillary flow or pressure are therefore the important elements. This fact permitted the use of plasma volume expanders across the front and the response was satisfactory. This was, of course, a compromise based on the relative non-accessibility of whole blood in the front lines.

The value of whole blood transfusions was appreciated in World War II. In Korea, the helicopter and the supply of whole blood available combined to permit the treatment of many casualties who would previously have died in transit or been considered hopeless. We literally poured blood into these men. Often the question was raised as to whether too much blood was used. We knew from experience that, if transfusion was slowed, hypotension and death resulted. Captain Prentice has summarized the blood volume studies which unequivocally demonstrated the justification for massive transfusions in most of the severely injured men. This experience with massive transfusions was unique.

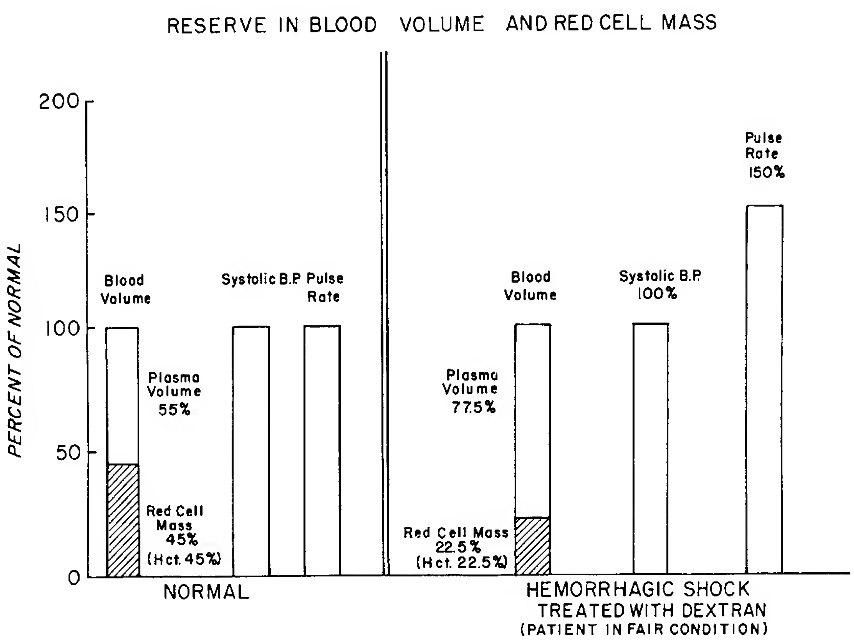

FIGURE 3.

The following three tables (tables 1, 2, and 3) demonstrate some of the practical observations. Table 1 summarizes the experience with 30 consecutive patients studied whose blood pressure at the time of admission to the hospital was zero as measured clinically. Nine patients required less than 15 pints of blood. There was no fatality. Twenty-one patients required over 15 pints and the mortality was 52 percent. In the latter group, the mortality in the seven patients with wounds limited to the abdomen was 100 percent in contradistinction to a mortality of only 12.5 percent of the eight casualties with wounds of the extremities. One of the implications of the latter comparison is the difficulty in controlling intra-abdominal hemorrhage. Greater immediate dividends will accrue from studies on methods of controlling hemorrhage than from studies on the mechanisms of late shock. Another implication from this study is that the amount of blood required for resuscitation is a better index of prognosis than is the blood pressure at the time of admission.

Table 1. Resuscitation of Battle Casualties—Admission Blood Pressure Unobtainable

Injury	Total		Receiving 15 or more pints of blood			Receiving less than 15 pints of blood		
	Number	Mortality (percent)	Number	Number died	Mortality (percent)	Number	Number died	Mortality (percent)
Abdominal only	10	70	7	7	100	3	0	0
Abdominal and extremity	6	50	6	3	50	3	0	0
Extremity only	14	7	8	1	12.5	6	0	0
Total	30	37	21	11	52	9	0	0

Table 2 summarizes the experience with 60 casualties (regardless of admission blood pressure) who required 15 or more pints of blood on the day of admission. Again continued hemorrhage was recognized as a major factor accounting for 10 deaths and Captain Prentice has data to indicate that many of the others died of blood volume deficiency in spite of massive transfusion and in spite of apparent hemostasis. Again, the sharp difference is noted between the mortality in the patients with abdominal and extremity wounds.

Finally (table 3), it was in this group who required massive transfusion that post-traumatic renal insufficiency developed. This complication is a direct or indirect result of the magnitude of the wound and the severity of the shock. Post-traumatic renal insufficiency cannot be predicted by evaluating the magnitude of the wounds or the

Table 2. Resuscitation of Battle Casualties—Patients Requiring 15 or More Pints of Blood in First 24 Hours

Injury	Total			Number dying of continued hemorrhage	Mortality excluding continued hemorrhage (percent)
	Number	Number died	Mortality (percent)		
Abdomen	16	13	81	7	67
Abdomen and extremities	20	10	50	2	42
Extremities	21	2	9. 5	0	9. 5
Chest	3	2	67	1	50
Total	60	27	45	10	34

Table 3. Resuscitation of Battle Casualties—Patients Requiring 15 or More Pints of Blood in First 24 Hours, Incidence of Renal Failure

Injury	Number living 3 days or longer	Anuria (percent)	Oliguria (percent)	Non-oliguric azotemia (percent)
Abdomen	9	22	11	11
Abdomen and extremity	14	28	0	7
Extremity	19	0	11	22
Chest	1	0	0	0
Total	43	14	7	14

Incidence of clinically significant renal failure=35 percent.

severity of the hypotension at the time of admission. It can best be predicted by the response to transfusion. The hypotensive patient with serious wounds, whose blood pressure responds sluggishly to transfusion in the face of apparent hemostasis, is a likely candidate for renal failure.

The primary cause of hypotension is a deficiency in blood volume. What about a deficiency of the sympathetic nervous system? We could seldom demonstrate such a deficiency. Vasoconstrictors have little or no place in the treatment of shock in the battle casualty. Their place is limited to meeting a deficiency in the function of the autonomic nervous system. This deficiency has been recognized only when the system was blocked by anesthesia or when there was an anatomical wound of the central nervous system. We have repeatedly treated the casualty with postoperative, refractory shock with vasoconstrictors. The blood pressure could be titrated for a few hours (fig. 4, A and B) but death was inevitable. To repeat, vasoconstrictors have an extremely limited place in the treatment of wound shock in the battle casualty.

VASOCONSTRICTORS IN THERAPY OF REFRACTORY WOUND SHOCK

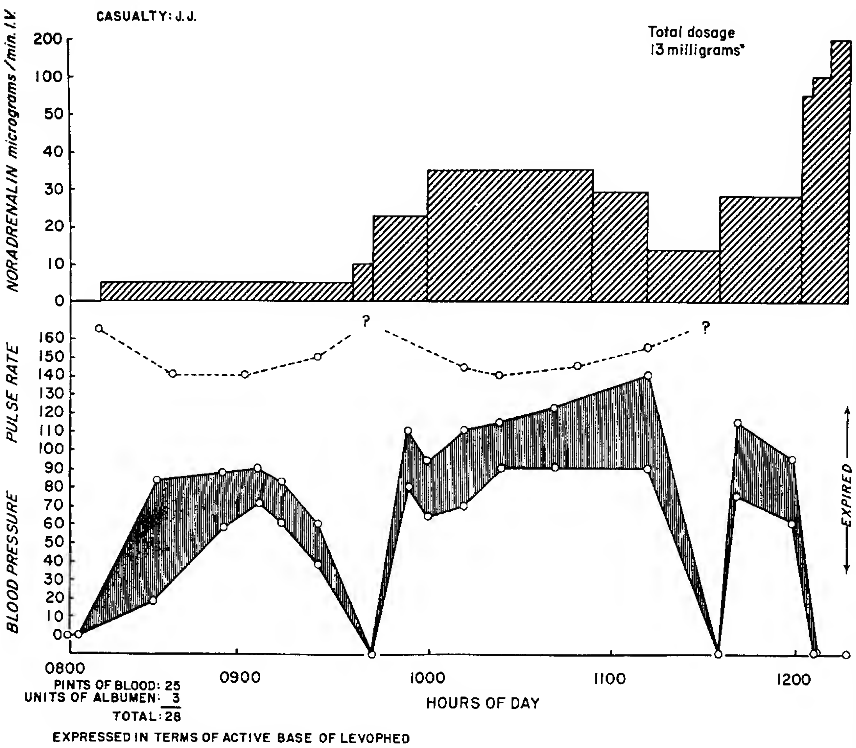

FIGURE 4A.

Clinical experience and blood volume measurements demonstrated the value of massive transfusions. In spite of continued transfusion and apparent hemostasis (fig. 5, A and B) some casualties died of refractory shock following anesthesia and operation. Lt. Strawitz was able to demonstrate pulmonary edema at autopsy in some of these patients. I am convinced that following massive tranfusion, an element of cardiac failure may develop. This concept includes an element of cardiac failure after transfusion and anesthesia. The cause of hypotension initially is blood loss. Following anesthesia and operation we often saw a form of secondary shock. This usually responded to additional transfusion and represented blood volume deficiency and diminished function of the sympathetic nervous system as a result of anesthesia. Those patients who did not respond postoperatively to blood transfusion died with pulmonary edema and, I believe, secondary cardiac failure. I cannot fully document our case. Studies at this time often revealed a rising plasma potassium concentration (figs. 6, 7) and an occasional patient would respond

dramatically to an infusion of calcium (fig. 8). Strawitz and Meroney have suggested the possible interrelationship of these three observations. They may be pointing to a citrate toxicity in the face of continuing transfusions and a relative hepatic insufficiency.

We speak of circulatory failure meaning the failure of circulation within the vascular tree. What we are really interested in is the "circulation" or diffusion between cells and extracellular fluid and between extracellular fluid and blood. This extravascular "circulation" or diffusion is the factor which determines cellular function and life.

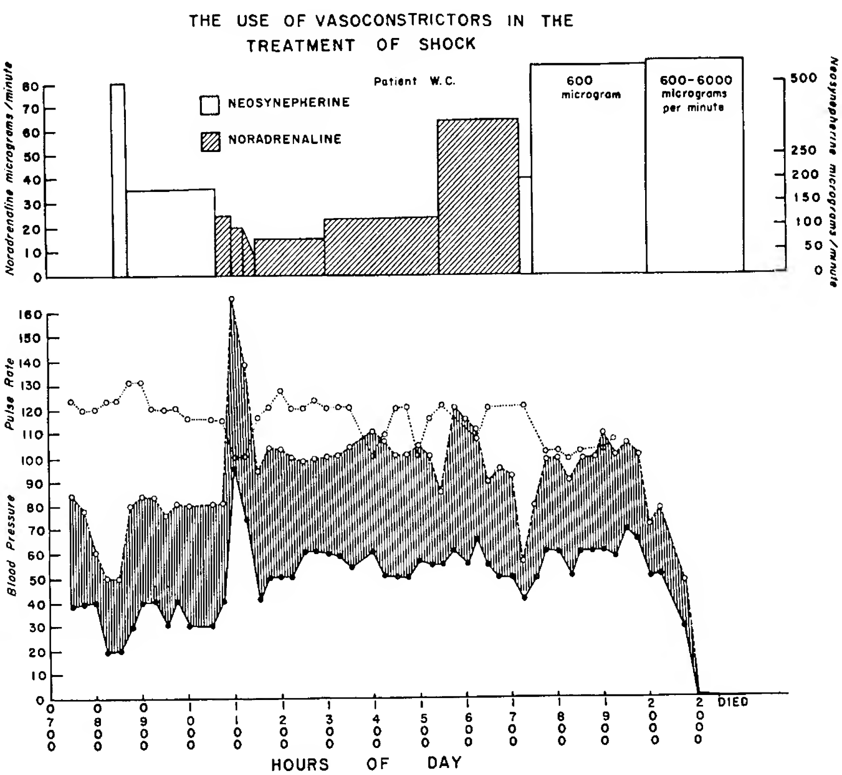

FIGURE 4B.

Capillary circulation is only the means of providing it. A rough approximation of this total body "circulation" or mixing can be gained from experiments with deuterium oxide. Schloerb has previously demonstrated that when the deuterium oxide was given intravenously to a normal subject, diffusion from the blood was immediate and equilibration occurred quite rapidly. In our studies of total body diffusion and mixing, the mixing was slighlty slower, but when deuterium oxide was given intravenously, the resultant curve, the deuterium concen-

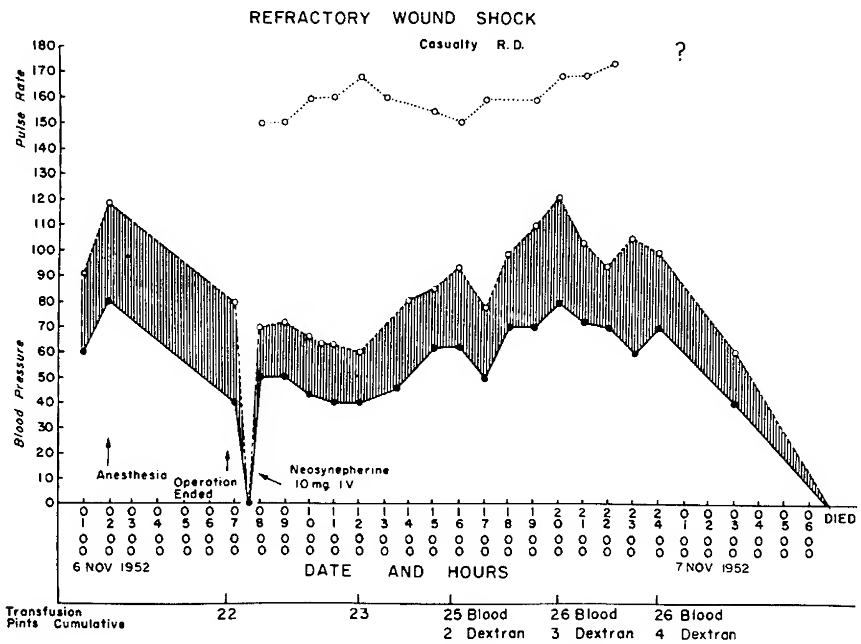

FIGURE 5A.

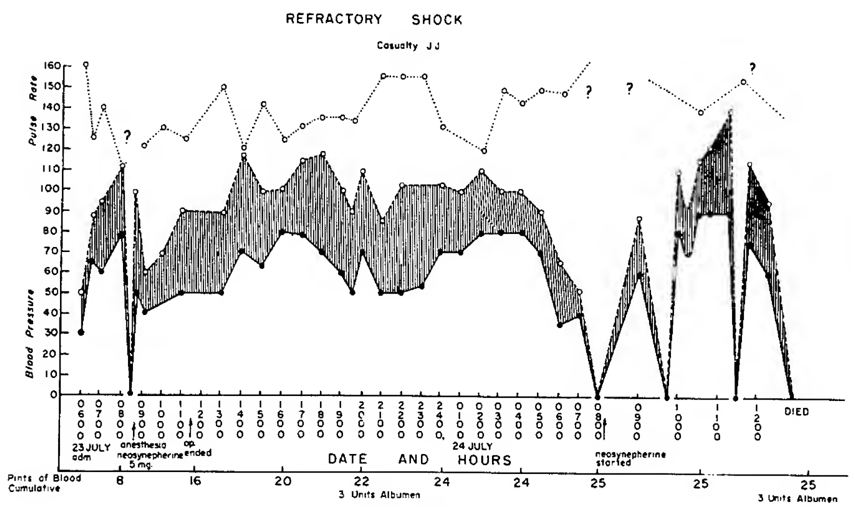

FIGURE 5B.

tration in venous blood of the opposite arm, reveals the rapid mixing and diffusion (fig. 9). A similar study from a patient in shock demonstrates the greatly retarded mixing. This is hardly due to a slower circulation time. It is due to a decrease in the effective capillary circulation—and so in the extracellular mixing and diffusion (fig. 10).

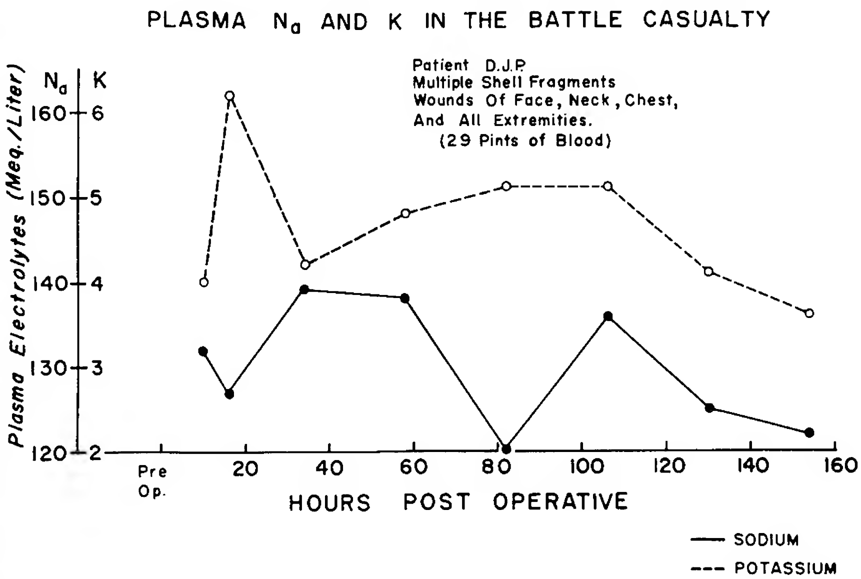

FIGURE 6.

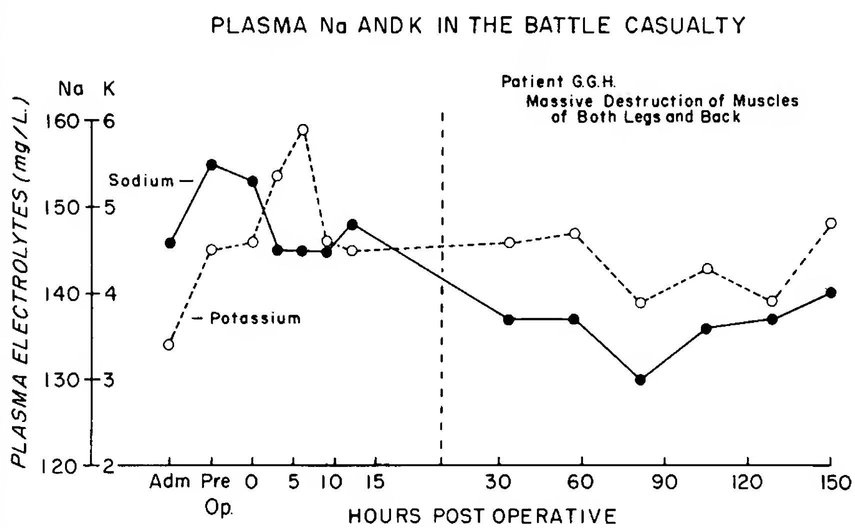

FIGURE 7.

This decrease in the effectiveness of the total body circulation leads to an exaggeration or aberration of the response of the function of every organ. If shock does not persist too long, no dangerous failure in organ function could be found. The blood volume is decreased and the total circulation is depressed. The hematocrit falls in extremity wounds and rises after abdominal wounds. The plasma

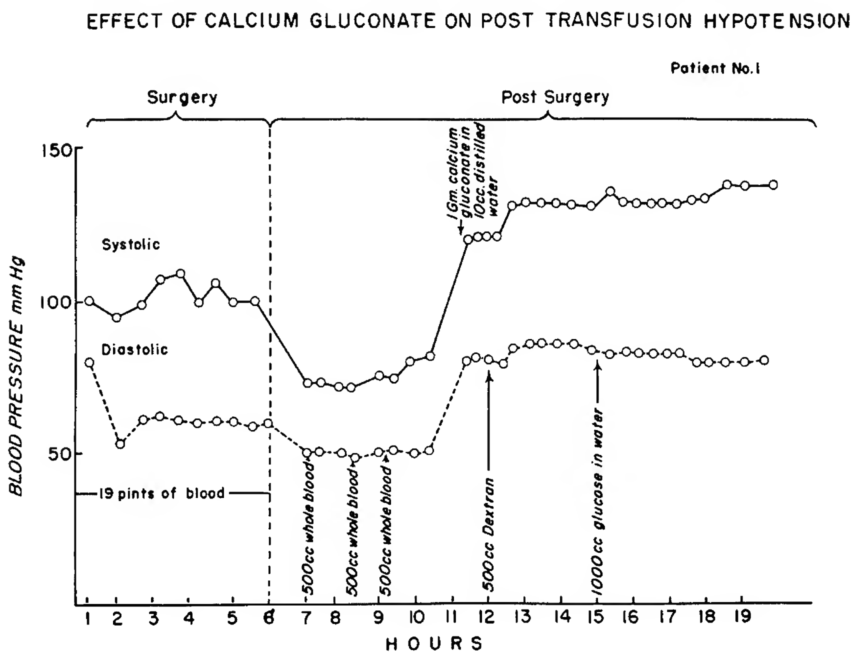

FIGURE 8.

sodium falls and the plasma potassium may rise. The function of the autonomic nervous system appears clinically in tact as evidenced by our clinical studies and the studies of Captain Stahl. The adrenal cortical response develops rapidly in spite of severe shock as indicated by the fall in eosinophile counts, the urinary retention of sodium and water, the diuresis of potassium, and the increased excretion of corticosteriods. Hepatic function, as measured by the above standard liver function tests, is depressed, but as measured by the more vital tests of metabolism appears generally adequate. Renal function appears in some aspects to be markedly depressed, presumably because of an exaggerated renal vasoconstriction. The clotting mechanism, the hematologic response and the bacterial defense all appear adequate in face of shock of short duration.

If the shock continues for a long period of time, cellular damage becomes so severe that the cells, organs or systems may lose their function. It may be the heart or brain which gives out first. Dr. Shorr feels that it is the liver which by release of ferratin, a vasodilator, makes prolonged shock refractory. Our studies with Dr. Shorr indicate that many of the casualties, who had been resuscitated from critical injuries, maintained a positive V. D. M. test (ferritinemia) for several days. Dr. Fine believes it is the bowel which is the most sensitive and which by the release of bacterial toxins makes pro-

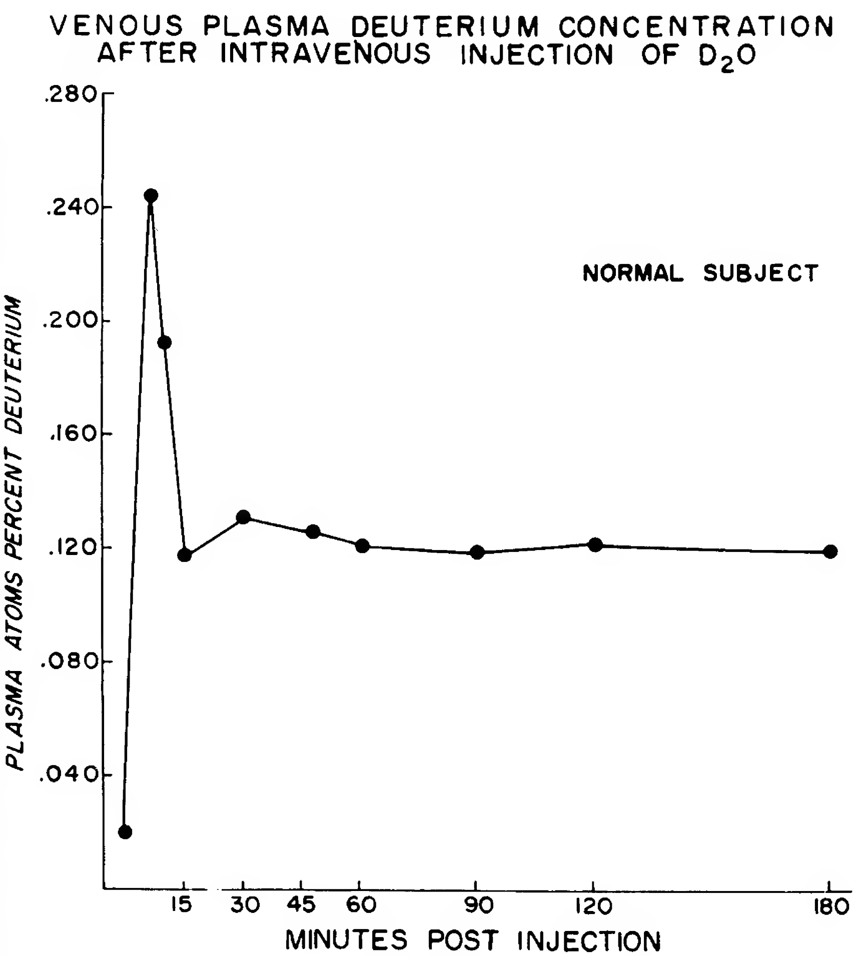

FIGURE 9.

longed shock refractory. We were seldom able to obtain bacterial growth from blood cultures on 170 of the most severely injured casualties. In our experience, kidney damage appeared to be the residual damage in casualties who barely lived.

In summary, the wound is a dynamic, not a static injury and continues to insult the body. The insult is greatly lessened by débridement. The treatment of wound shock is, first, a restoration and maintenance of the blood volume, preferably with blood, and second, surgical correction of the wound. The body responds in its entirety to severe trauma. Anesthesia, by blocking this response, is a tremendous injury to such a casualty. Although anesthesia is necessary in order to lessen the influence of the wound, it, per se, temporarily furthers the injury.

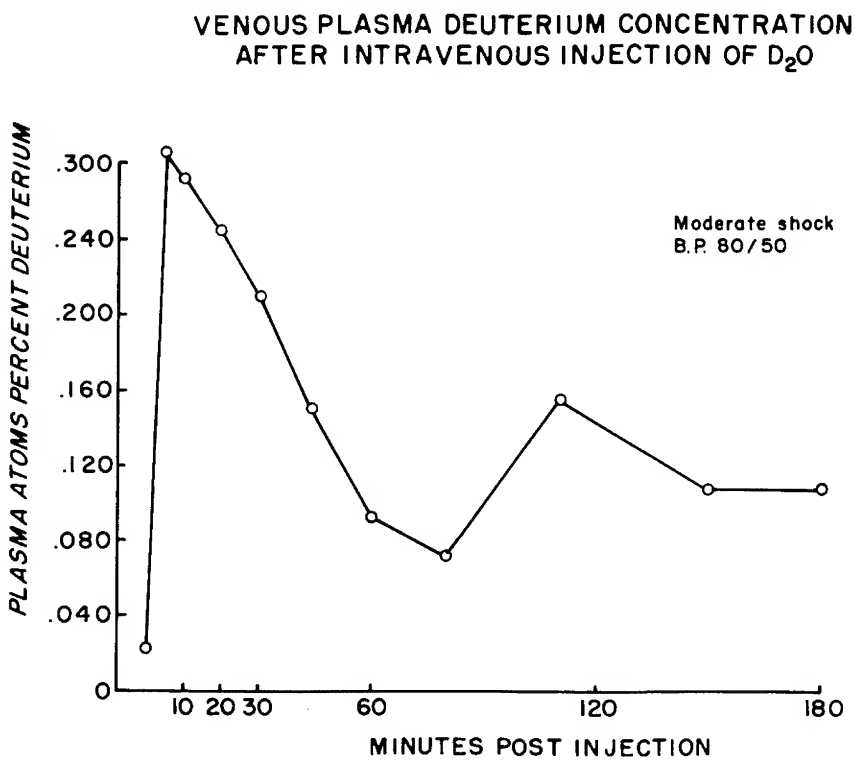

FIGURE 10.

At an average time of 3.5 hours after injury, irreversible shock was not recognized prior to anesthesia in 4,000 Korean casualties. Following anesthesia and operation, hypotension may be quite refractory but will characteristically respond to continued transfusion. Even after the use of massive transfusions, the blood volume was often surprisingly low.

Following injury, the function of every system and organ in the body appears to be altered. The alteration is proportional, in magnitude and duration, to the magnitude of the original injury. Hypotension characteristically accentuates the changes.

What are the problems for continued investigation? I should suggest the following:

1. A continued survey of resuscitation at the battalion level.
2. Improved methods of controlling hemorrhage.
3. The effect of anesthesia on the circulation.
4. The etiology, prevention and treatment of post-traumatic renal insufficiency.
5. The fate of transfused blood in the injured man.
6. The development of a better plasma volume expander.

7. The treatment of casualties with abdominal injuries.
8. The study of the wound, the response to injury, the resuscitative tools and methods. This must be the approach rather than a study of the hypotensive state, per se.

DEBRIDEMENT*

Captain Alvin W. Bronwell, MC
Major Curtis P. Artz, MC
and
Captain Yoshio Sako, MC

Débridement is a surgical procedure for the removal of injured and devitalized tissue, blood clots, foreign bodies, and for the control of hemorrhage. This is a procedure that is carried out initially to stop the continuous destructive process of the wound and to prepare it for the initial reparative phase of wound healing. The definitive procedure (delayed primary closure) is performed at a later date.

There are many differences between the management of wounds in a combat theater and in civilian practice. When a surgeon is first indoctrinated into forward surgery, he feels that leaving war wounds open is incomplete treatment because in civilian surgery the initial care is a definitive reparative procedure. Definitive surgery cannot be carried out in the forward hospital initially because: (1) usually the time lag is longer for war casualties than for civilian casualties; (2) after initial treatment, a war casualty must be evacuated at an early date to a hospital further to the rear, thus making it impossible for proper immobilization of the injured area; and (3) because of evacuation, the patient must be cared for by various physicians. These physicians cannot be as familiar with the condition of the wound as the surgeon who treated the patient initially. Careful postoperative observation for wound infection, excessive swelling, or necrosis of injured tissue is impractical during transportation.

Since these factors make it impossible to follow the patient closely from the time of injury to the completion of wound healing, it is necessary that a safe procedure be followed so that uniformly good results can be obtained. Thus the initial phase of treatment in the forward hospital consists of an adequate incision and excision of devitalized tissue. Delayed primary closure is completed at a later date, usually in another hospital.

*Presented 21 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

Débridement of Different Types of Tissue

All wounds should be treated exactly the same, regardless of the time lag. The skin about the wound should be shaved, washed with a detergent containing hexachlorophene, and thoroughly irrigated.

Skin. Débridement of the skin may be divided into two aspects: first, exposure of the depth of the wound by adequate incision and, second, excision of the devitalized skin. In order to reach the base of the wound for excision of devitalized tissue, it is necessary to enlarge the skin defect by a long incision. Inadequate incisions give poor exposure to the deeper portion of the wound, which may result in incomplete removal of devitalized tissue and difficulty in control of hemorrhage. Skin at the point of entrance of a missile may be shredded, discolored and very dirty; but it may still be viable. Wide excision of skin is unnecessary. In general, approximately 1/8 inch of skin should be excised from the injured wound edge.

Longitudinal incisions should be used in extremity wounds to prevent contracture and to permit easier dissection of deep muscle planes. A Z-type incision is desirable where wounds are present in a flexion crease about a joint.

At the completion of the debridement, the skin is allowed to remain open except in wounds of the scalp, face, neck and scrotum. In injuries to the hand, an attempt should be made to give cover to vital structures. This can be done by approximating the skin loosely with one or two sutures. In wounds about the face and scalp, excision of skin should be kept to a minimum; and the edges should be undermined, if necessary, in order that approximation can be made without tension.

Subcutaneous Tissue. Débridement of the subcutaneous tissue is not difficult. The entire layer of subcutaneous tissue must be excised in very dirty wounds. In other instances, most of the injured fat, debris and blood clots can be removed by irrigation.

Fascia. It is difficult to determine when fascia is viable, but it must be excised when it is shredded and dirty. The fascia should be incised for at least the entire length of the skin incision to allow adequate observation of the underlying muscle and to prevent constriction and necrosis of the muscle when postoperative swelling occurs. The fascia must remain open to provide adequate drainage of the deeper tissues. Without proper drainage of the base of the wound, serum and blood may accumulate to form a pabulum for bacterial growth and subsequent infection. In most instances, the fascia is incised along the direction of its fibers. In some instances, such as in wounds of the fascia lata, a cruciate incision must be made in order to give adequate relaxation.

Muscle. Muscle is the most important and difficult tissue to débride. Dead muscle produces an excellent medium for the growth of bacteria in the wound. The infection of greatest clinical significance is caused by organisms of the *Clostridium welchii* group. Clostridial myositis frequently necessitates the amputation of an extremity and may even cause loss of life.

Muscle is difficult to débride because the operating surgeon has no clear-cut criteria or tests by which to judge the viability of muscle. Usually the surgeon draws upon his past experience in observing color of the muscle, its consistency, its contractility and its ability to bleed.

A study was conducted by the Surgical Research Team in Korea in an attempt to determine the value of various criteria for viability of muscle. They obtained 60 muscle biopsies at the time of débridement and graded them as to color, consistency, contractility and ability to bleed. These biopsies were then studied by the pathologist and categorized according to minimal, slight, moderate, severe and complete necrosis. In correlating the gradation of various criteria with the amount of necrosis in the microscopic sections, it was found that consistency, contractility and ability to bleed were acceptable, dependable criteria. There was less correlation between color and amount of necrosis.

The actual technic of débridement is important because these criteria must be carefully evaluated. Adequate exposure and illumination into all portions of the wound are essential. The wound must be irrigated frequently to wash out clots in order to obtain a better view of the muscle. Hemostasis is sometimes difficult, but it must be maintained during operation in order to permit proper visualization. Bold excision of dead muscle is required. Great care must be taken to prevent surgical injury to vital structures in the deeper muscle layers.

Bone. In comminuted fractures, an effort is always made to leave bone fragments *in situ.* Likewise small bone chips should not be removed if they are in close approximation to the fracture as they will usually grow and act as a graft. If the chips are scattered throughout the wound, they should be removed, as they may act as foreign bodies. In all fractures, the bone is covered either by placing muscle over the exposed area or by approximating the skin loosely in cases where muscle and subcutaneous tissue are absent. Fractures are reduced manually. The extremity is then placed in a cast to preserve length and immobilize the injured part.

Joint Spaces. Injuries to the joint spaces are treated by opening the joint and removing any foreign bodies. The joint space is irrigated with saline solution. The joint capsule is closed and reinforced

by suturing subcutaneous tissue over it. Loose particles of cartilage must be removed or they will act as foreign bodies.

Débridement of Various Regions

Wounds of the Scalp. Débridement of wounds of the scalp is carried out, layer by layer, by excision of devitalized tissue and by thorough irrigation and primary closure. This type of treatment is possible because the increased blood supply to the scalp promotes rapid healing. Hemostasis may be difficult, but can be achieved by sutures approximating the wound edges. In some instances, it becomes necessary to make lateral, relaxing incisions to release sufficient skin for primary closure of the wound. Since pressure dressings are difficult to apply to this area, wounds of the scalp should be checked at frequent intervals so that hematoma formation will not be overlooked.

Wounds of the Face. The primary consideration in treating wounds of the face, especially about the oral cavity, is the maintenance of an adequate airway. A tracheotomy must be performed in those instances where profuse bleeding into the nasopharynx makes the establishment of an airway difficult. After an adequate airway is assured, the bleeding points should be controlled, the entire wound cleansed, and devitalized tissue excised. Wounds of the face are also closed by primary suture, principally for cosmetic reasons. Wounds in this area heal well because of the excellent blood supply to the face. If a fracture of the mandible or maxilla is present, the teeth should be wired in apposition.

Wounds of the Neck. Wounds of the neck present three essential problems: (1) obstruction of the airway, (2) trauma to a large blood vessel, and (3) injury to the esophagus and trachea. At the slightest indication of obstruction of the airway, a tracheotomy must be performed immediately. To delay for definite signs of obstruction may be fatal.

Débridement is not performed in wounds of the neck when conservative management of an underlying vascular injury is elected. Simple wounds of the neck are débrided and closed by primary suture. Deeper wounds require drainage.

The patient must be examined closely to determine the course of the missile after its entrance into the neck. X-ray examinations are of great value in assisting in this procedure, especially when a foreign body is retained. If it cannot be ascertained whether the missile has traversed the trachea or esophagus, exploration of the neck with exposure of the esophagus and trachea is necessary. An incision is made along the anterior border of the sternocleidomastoid muscle. After the subcutaneous tissue has been incised, it is possible to dissect between

fascial planes and expose the trachea and esophagus. If these structures have been injured, they are repaired with interrupted sutures. Rubber tissue drains are placed at the base of the wound and brought out at the upper and lower angles of the incision and the wound is then closed. If indicated, the contralateral side is similarly treated.

Wounds of the Extremities. Wounds of the extremities require careful examination preoperatively to determine the extent of damage and the presence of bone, nerve and vascular involvement. An accurate record should be made of these findings. Various types of wounding agents produce different patterns of tissue damage. For instance, a high-velocity missile will usually produce a small wound of entrance and of exit, with massive destruction of tissue within the extremity. Lower-velocity missiles of comparable size produce less cavitation and internal muscle destruction. It must be emphasized that all missile wounds of soft tissue are characterized by greater muscle damage than is apparent from the external examination of the injured part. Routine roentgenograms of the extremities are advised for the detection of retained metallic fragments.

The wound should be exposed by enlarging the skin opening in both directions by a longitudinal incision. Through-and-through wounds should be explored by adequate longitudinal incision on each side. In all large wounds and in wounds in which vascular involvement is suspected, a pneumatic tourniquet should be placed about the extremity before operation. It need not be inflated unless difficult hemorrhage is encountered. In many instances, an inflated tourniquet will cause troublesome bleeding by increasing venous engorgement.

The surgeon should have a thorough knowledge of the anatomy of the involved region to avoid unnecessary trauma to blood vessels and nerves during excision of devitalized tissue. Extensive fasciotomies are necessary in order to prevent the necrosis which may result from muscle swelling.

All devitalized muscle must be excised. In areas of small muscle mass where excessive excision may jeopardize function, such as the forearm and hand, débridement should be conservative. In areas of large muscle masses, such as the thigh and buttocks, débridement must be more radical. Devitalized tissue remaining in deep muscle bundles gives rise to serious infections, septicemia and clostridial myositis; whereas the incidence of these complications is not so great in the more superficial, open wounds of the hand and forearm.

When major vascular laceration is suspected, the blood vessel should be exposed, explored and repaired prior to actual débridement of the wound. This is particularly true in the femoral triangle and in the popliteal areas.

Wounds of the Hand. In débridement of wounds of the hand, preservation of maximum function is essential. In all cases of hand injury, it is very important that a tourniquet be placed on the arm in order that the procedure may be conducted in a bloodless field. The minimum amount of tissue, especially skin, should be removed. The surgeon should be conservative in amputation of digits. Blood clots and debris should be washed out and devitalized tissue excised. No attempt should be made at this time to repair or tag nerves or tendons. Only small, loose chips of bone should be removed. Bone fragments may be aligned by manual reduction. Finally, the wound should be thoroughly irrigated and the skin approximated loosely by one or two sutures over the deep structures. If the skin on the hand is closed tightly, swelling and further loss of skin may occur as a result of necrosis. In addition, tight closure of hand wounds is frequently followed by infection beneath the skin, thus delaying wound healing and producing a greater loss of function. The hand should then be splinted in a position of function. The tips of the fingers should remain exposed for observation of circulatory status.

Superficial Wounds of the Abdomen and Chest. Almost all superficial wounds of the chest and abdomen are débrided and left open. After débridement, deep sucking wounds of the chest are closed tightly in layers. In massive wounds of the abdominal wall, the peritoneum and fascia should be closed and the skin should be left open. Incisions for abdominal exploration and for colostomy should never be made through the wound.

General Aspects of Débridement

Immediately after admission, antibiotics should be given. The intravenous route is preferred in order to assure adequate blood levels. Postoperatively, antibiotics should be given routinely for a maximum of 5 days and thereafter only on specific indications. All patients should receive tetanus toxoid or antitoxin. Gas gangrene antitoxin is of no value. The prevention of clostridial myositis depends upon the adequacy of the débridement.

Not all débridements are simple surgical procedures. The small, superficial wound is not difficult to débride. Débridement of moderate-size, soft-tissue wounds can usually be carried out by the surgeon and a scrub technician. In more extensive débridements, the surgeon requires a first assistant. Not infrequently, greater bleeding is encountered than is expected; and an excessive amount of blood loss occurs because technical assistance is not available to provide adequate exposure. Because of the slow, constant loss of blood from the damaged muscle, hemorrhage is always greater than the surgeon anticipates.

When several areas of the body require débridement, it is wise to use two teams in an attempt to decrease the operating time and the blood loss.

Some larger wounds are not difficult to débride; but they require expert judgment to determine the proper amount of muscle to be removed. Débridement of large wounds is not a task for the immature surgeon; it requires the ability of the more experienced.

One of the great problems in surgery is the management of massive wounds of the buttock and upper thigh. These wounds present two difficult aspects, namely, control of hemorrhage and determination of the exact amount of muscle to be excised. A tourniquet cannot be applied to control hemorrhage. It is almost impossible to achieve adequate pressure for hemostasis by a dressing. General oozing may continue from the massive muscle area after débridement and ligation of all visible bleeding points. When a large amount of muscle is involved, it is difficult to determine the exact amount to be excised. When high-velocity missiles cause wounds of the thigh or buttock, frequently they carry damage along fascial planes and between the muscle bundles. If devitalized deep muscle remains, clostridial myositis or pockets of infection may develop. In large wounds of the buttocks and upper thigh, it is wise to take a "second look" on the second and third postoperative day. At that time, remaining necrotic tissue is easily recognized and further débridement can be carried out.

Large missile fragments in soft-tissue wounds are removed. Small fragments are removed if easily accessible. If further trauma is required to effect their removal, they are allowed to remain in place. Plain catgut is preferred for ligatures, since foreign-body reactions are not uncommon following the use of silk.

After careful hemostasis has been achieved, the open wound should be covered with fine-mesh gauze and a large occlusive pressure dressing applied. Packing the wound with gauze prohibits drainage. When plaster casts are applied for the immobilization of fractures, a longitudinal, half-inch segment should be removed and the circular dressings cut down to the skin. This procedure prevents undue pressure when edema occurs.

Summary

Débridement, or the excision of devitalized tissue, is the initial treatment for all soft-tissue wounds. Long incisions into skin should be made to insure adequate exposure of the deepest portion of the wound.

The incision in the fascia should be of sufficient length to provide adequate decompression of the underlying edematous muscle.

Consistency, contractility and ability to bleed appear to be the most reliable criteria for the determination of viability of muscle. Inadequate removal of devitalized muscle may lead to clostridial myositis and septicemia.

After adequate débridement, wounds of the scalp, face and neck, and sucking wounds of the chest should be closed by primary suture. Blood vessels, tendons, nerves, bone, testicles and open joint spaces should be covered by loose approximation of the surrounding tissue or skin. All other soft-tissue wounds should be let open.

Débridement is most difficult to carry out in large wounds of the buttocks and upper thigh.

Experiences in the Korean conflict have re-emphasized the safety and efficacy of débridement and delayed primary closure in the management of soft-tissue wounds.

OLIGURIA*

Major William H. Meroney, MC

I. *General Considerations*

Renal insufficiency has been described in association with numerous pathologic conditions which do not involve the kidneys primarily. Insults to non-renal systems of the body may provoke compensatory responses which protect the organism as a whole but damage the kidneys secondarily. The prime example of this phenomenon is shock, in which blood in shunted away from organs whose functions are not immediately necessary for survival. By the time critical functions are restored, organs with low priority for blood, such as the kidneys, may have undergone ischemic changes of severe degree. Insults to non-renal systems may release to the plasma pigment or other intracellular materials which are concentrated in the kidneys and produce obstruction or cellular degeneration. There are numerous other ways in which kidneys may be damaged, but these two are considered to be of greatest importance in war or traumatic disaster.

Once renal damage has occurred, it may assume greater importance than the original condition as a factor in prognosis unless specialized treatment is instituted. Comprehensive studies by the Board for the Study of the Severely Wounded in World War II (*1*) revealed that the degree of oliguria was correlated with the mortality rate. In a group of 186 severely wounded men with an overall mortality rate of 35 percent, those with a urinary output of 100 to 600 cc. per 24 hours had a mortality rate of 47 percent, and those with a urinary output of less than 100 cc. per 24 hours had a mortality rate of 91 percent. The researches conducted by these and many other investigators provided a greater understanding of renal failure which allowed development of newer methods of treatment which lower the mortality rate.

In the Korean war renal failure as a complication in the severely wounded was comparable with that seen following shock in World War II. Pigment nephropathies were not recognized as significant causes of renal failure in this study, a fact which is a tribute to the excellence of the blood replacement program and which probably also

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stems from the infrequent occurrence of crushing injuries. Members of the Surgical Research Team observed that oliguria occurred most frequently in the individuals who were most severely wounded and whose resuscitation was most difficult. Of the first 10 such patients observed, 9 died of potassium intoxication.

In April 1952, an artificial kidney was put into operation by the Surgical Research team at the Renal Insufficiency Center at Wonju, about 75 miles behind the main line of resistance. This unit was attached to the 11th Evacuation Hospital and was operated as a joint effort of the Army Medical Service Graduate School in Washngton, the 406th Medical General Laboratory in the Far East Command, and the 8th Army Medical Service in Korea. During the 16 months of its operation this unit received approximately 160 patients who had, or initially were suspected of having, renal insufficiency. The greatest number of patients cared for at any one time was 11, and the average number was about 4. However, the intensive care and study given these patients required that three to five internists, one surgeon, four to six nurses, six to nine corpsmen, and two to four laboratory technicians work full time on this effort. In addition, all of the personnel of the hospital, particularly the anesthesiologist, pathologist, laboratory technicians, supply officer and utilities officer, contributed significantly to this effort. The operation of the unit centered around the artificial kidney and the laboratory, but all of the personnel and facilities utilized in the care of any seriously ill patients were even more concerned for these patients.

The immediate net result of this investment was a reduction in overall mortality rate from about 90 percent to about 55 percent. When the biochemical abnormalities resulting from renal failure were controlled, the degree of renal failure no longer paralleled the mortality rate. A less tangible but probably more important result of the control of renal failure was the dissociation of the effects of uremia from the effects of other clinical disorders. Upon the completion of 6 hours of treatment with the artificial kidney, a patient is momentarily relieved of uremic symptomatology, and the remaining symptoms can be traced to their proper source.

If the source of such symptoms can be located and corrected, the symptoms resulting from uremia alone can then be assessed as they reappear in ensuing days of oliguria. The importance of such maneuvers lies in the difficulty of assessing symptoms and assigning priority to therapeutic procedures in a man with multiple abnormalities in addition to oliguria. If one is not to be confounded by the complexities of such a patient, the clinical patterns to be expected from each disorder alone must be established. It was not uncommon

in Korea for a moribund patient to be rushed as an emergency to the Renal Center when, in fact, none of his symptoms were the result of uremia. The surgical care which may have represented the patient's only chance for survival was not given by those best qualified and in the best situation to give it. Other patients whose threats to life were primarily of renal origin could have been treated more satisfactorily if the information gained at the Renal Center had then been available in the forward area. It is the purpose of this report to outline the concepts and methods employed at the Renal Center which appear to have the greatest practical application, with specific reference to 48 renal and 11 non-renal patients observed by the author. The system presented is subject to revision, as analyses now pending are completed, as further information becomes available from other workers, and as any divergent opinions are resolved. A more detailed account of individual cases and raw data is recorded elsewhere (*2*).

II. *Recognition and Transfer*

The diagnosis of renal insufficiency should be suspected if the urine output falls below 500 cc. per 24 hours, about 20 cc. per hour. The patient and his records should then be re-examined with the following possibilities in mind:

1. *Reflex oliguria.* This term is used to designate the transient oliguria which occurs following surgery or other trauma. The condition may not be reflex in origin, but it appears to be a normal response to this type of stress and lasts only a few hours.

2. *Hypotension.* The blood pressure in the renal artery is an essential component of renal filtration pressure. When hypotension is observed in the arm, renal filtration can be expected to be diminished. The resulting oliguria causes an increase in plasma NPN which can be misleading, because a patient with persistent hypotension may have central nervous system signs which resemble those of uremia at a later stage. It is important to distinguish the conditions because the treatment is quite different. The most practical approach to the differential diagnosis is to defer a diagnosis of renal failure until normal blood pressure is restored. The condition which produced the hypotension should receive first attention, because it likely will kill or be cured before renal failure, if it be present, requires any treatment.

3. *Dehydration.* A severe degree of dehydration is required to produce oliguria of 20 cc. per hour, and either history or physical examination should confirm this unusual diagnosis. If any question remains, the high specific gravity of urine excreted by normal kidneys during dehydration should settle the point, because the urine of acute post-traumatic renal failure characteristically has a low specific grav-

ity. The practice of administering a fluid load as a test for dehydration is dangerous and should not be necessary.

4. *Obstruction.* In the post-traumatic state urinary tract obstruction is suspected when there is flank pain with genital radiation, when the scanty urine contains crystals of drugs or heme casts, or when there is total anuria. Even the most severe cases of renal insufficiency usually are painless and the patients excrete 30 to 40 cc. of urine per day. If there is no urine whatever, first attention should be given the urethral catheter, for obstruction by mucus is not uncommon. Daily irrigation of the catheter with a bland fluid which is measured when instilled and recovered should prevent this complication. If obstruction is still suspected, cystoscopy and catheterization of the ureters are indicated.

5. *Acute tubular nephrosis.* If a patient with the usual state of hydration excretes less than 20 cc. of urine per hour after 5 to 10 hours of normal blood pressure, and there is no evidence of obstruction, the diagnosis of acute renal failure is justified. Pathologically, this lesion was first described as epithelial necrosis in the lower segment of the tubule, but subsequent studies indicate that the necrosis occurs throughout the length of the tubule (*3*). Functionally, there is serious impairment of the capacity of the kidneys to excrete or conserve selectively the substances in excess or in scarce supply. During the acute stage the problem is excretory. All of the plasma substances which normally appear in the urine accumulate in the plasma, where some of them are toxic. The renal lesion is potentially reversible, and if the patient can be maintained for the few days or few weeks required for regeneration of the tubular epithelium, spontaneous diuresis will occur. During the diuretic phase, the problem is lack of conservation. Scarce and essential substances are washed out in the copious urine flow, and serious chemical deficits can occur.

Once the diagnosis of renal failure has been made, it is essential that the symptomatology be re-appraised to establish which components are uremic in origin. When one is faced with a deteriorating clinical status in a patient with serious wounds and oliguria, there is a strong tendency to blame uremia for all of the symptoms and to neglect other disorders. With two exceptions, the symptoms of uremia do not appear, in our experience, until the fifth to eighth day of anuria when the NPN is 250 to 300 mg. per 100 cc. The first exception is overhydration, which is not really a symptom of the patient's disease but of the doctor's error. The second exception is severe potassium intoxication, which only occurs as a sequel of incomplete care of other features of the patient's condition. If neither overhydration nor potassium intoxication is present, anuria must persist for many days before it provokes symptoms.

It follows that other pathologic processes should be sought in a patient who is symptomatic during the first few days of anuria. Symptoms which resemble those of uremia are observed in patients with wound infection, generalized sepsis, or shock, but the offending agents cannot be dialyzed from the patient's plasma. There is no gain but potentially total loss in transferring such a patient to a renal center. If the basic condition cannot be corrected, there is even less chance of success after the delay and trauma of evacuation. If such a patient is to survive, resuscitation and débridement must be completed before transfer, and he must be able to maintain a blood pressure of more than 100 mm. Hg. throughout the journey without stimulants or infusions. Once these conditions are fulfilled, the oliguric patient can be transferred for definitive care of uremia with good prospects for success.

III. *Management*

The methods for management of acute renal failure and allied conditions which were developed from the Korean experience have general application and are reviewed below. The problems in management are considered in order requiring first action by the physician.

A. *Immediate Problems.*

1. *Fluid balance.* First and continuing consideration should be given to the prevention of overhydration. The evils of water intoxication are well known, yet this preventable complication is quite common. The total fluid intake per 24 hours should be in the range of 500 to 600 cc. plus the measured output, increasing to about 700 to 800 cc. plus the measured output if the weather is hot or the patient is feverish. The measured output usually is the total of urine and gastric suction, although diarrhea, not present in our cases, might increase the output significantly. This average intake allowed a daily weight loss one-half to one pound without producing clinical evidence of edema or dehydration.

The best route for administration of the fluids is oral if the patient is able to tolerate them. In our patients, however, oral fluids, even when given by duodenal tube, provoked vomiting. This complication compounded the problems of fluid and electrolyte balance, as well as adding the risk of aspiration pneumonia, and so the intravenous route was used almost exclusively. Restriction of oral fluids can be quite difficult. These patients often suffer a cruel thirst, yet their thirst is not an accurate gauge of their needs. If allowed to drink all they desire, they will literally drown themselves. When denied fluids they develop great craftiness in pervailing upon compassionate neighbors and attendants for small sips of any fluid or for pieces of ice, which is

bountiful and easily-overlooked source of water. When unobserved they will quaff heartily from flower vases, emesis basins, or urinals with great stealth and cunning. It is the physician's responsibility to prescribe the proper amount of water and to insure that no violation of his order occurs. Careful oral hygiene and unlimited chewing gum together with an explanation for the reasons which compel the apparent cruelty, are usually adequate to control thirst. The amount of water prescribed must contain all the solids to be administered during the 24 hours, and these will be discussed later.

2. *Potassium intoxication.* The only chemical abnormality which is likely to kill a patient in the first week of uremia is potassium intoxication. Normally potassium exists in high concentration inside cells but does not exceed 5.5 mEq./liter in the plasma. Normal daily catabolism of cells provides the plasma with a small quantity of potassium which is readily excreted. This amount of potassium can be handled by an anuric patient for many days, even several weeks, without accumulation of significant quantities in the plasma (*4*). However, the basic condition which originally produced the renal insufficiency often is characterized by excessive loss of potassium from cells. This was especially evident in our patients, many of whom had suffered extensive tissue damage from trauma or infection, and the plasma potassium rose to high levels as early as the second day of oliguria. Devitalized tissue, whether permanently destroyed or temporarily embarrassed by trauma, infection, chemical or physical agents, or hypoxia, gives up potassium to the plasma (*5*). In the plasma, not in the tissues, potassium is exceedingly toxic, and the first and most important evidence of toxicity is cardiac.

The toxic effect of potassium on the heart is recorded on the electrocardiogram long before any other signs or symptoms appear. The degree of electrocardiographic abnormality produced by a given excess of plasma potassium will vary widely, however, depending upon the activity of other factors. Under experimental conditions, such as the infusion of potassium into the plasma of normal dogs, it has been shown that the electrocardiographic effects of progressive increments of plasma potassium are quite consistent (*6*). In clinical situations, however, the electrocardiogram has not previously been shown to be a reliable gauge of the plasma potassium level (*7*). The electrocardiogram records function of the heart, and the function with respect to potassium is the result not only of the absolute level of plasma potassium, but also, of factors which influence the effects of potassium. The electrocardiogram is, in fact, an accurate gauge of the plasma level of potassium in man, when there is no abnormality except hyperpotassemia (*8*). The discrepancies lie in the rarity with which pure hyperpotassemia occurs. In the oliguric patient, all of the

plasma substances which normally are excreted in the urine, of which potassium receives first attention, are retained within the body, and some of these substances affect the behavior of potassium.

The retention of inorganic phosphate, though not of itself harmful, regularly produces a fall in the level of plasma calcium during oliguria. Figure 1, which is a graph of random pairs of phosphate and calcium determinations in oliguric patients, demonstrates the consistency with which a given excess of plasma phosphate produces a predictable deficit of plasma calcium. A deficit of plasma calcium is of cardinal importance during oliguria, because calcium is a specific antagonist of potassium, and hyperpotassemia and hypocalcemia occur at the same time.

As plasma potassium rises, the degree of toxicity recorded by the electrocardiogram is consistent with the plasma level only if plasma calcium is maintained. Otherwise, the electrocardiographic abnormality and the threat to the patient's life are much more serious. Since, in oliguria, plasma calcium regularly is depressed by a rise in plasma phosphate at the same time that plasma potassium rises, the electrocardiogram of the untreated patient bears little relationship to the plasma level of potassium. Replacement of the calcium deficit produces a striking improvement of the electrocardiogram, which then is reverted to that degree of abnormality characteristic of the

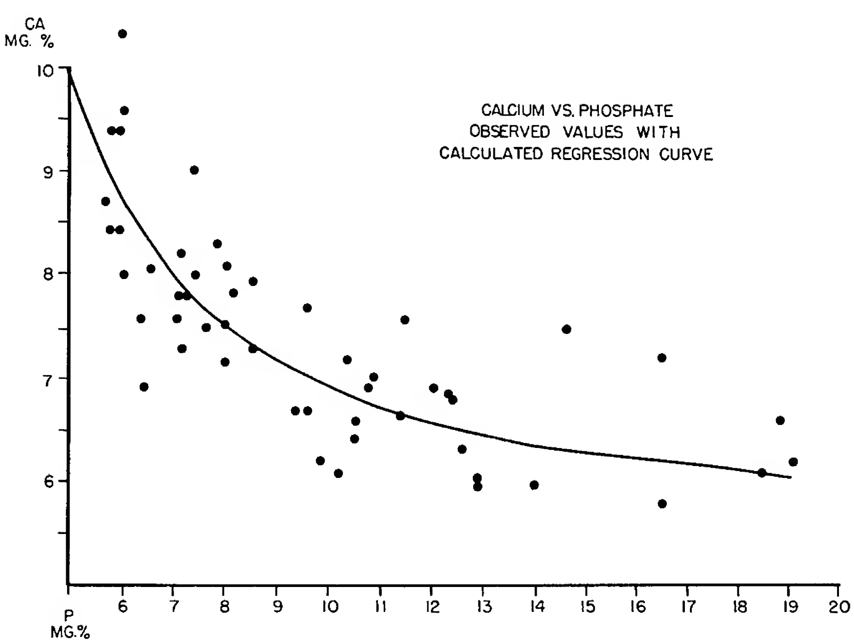

FIGURE 1.

plasma potassium level. Figures 2 and 3 demonstrate the effect of intravenous infusion of calcium in uremic patients with far-advanced potassium intoxication.

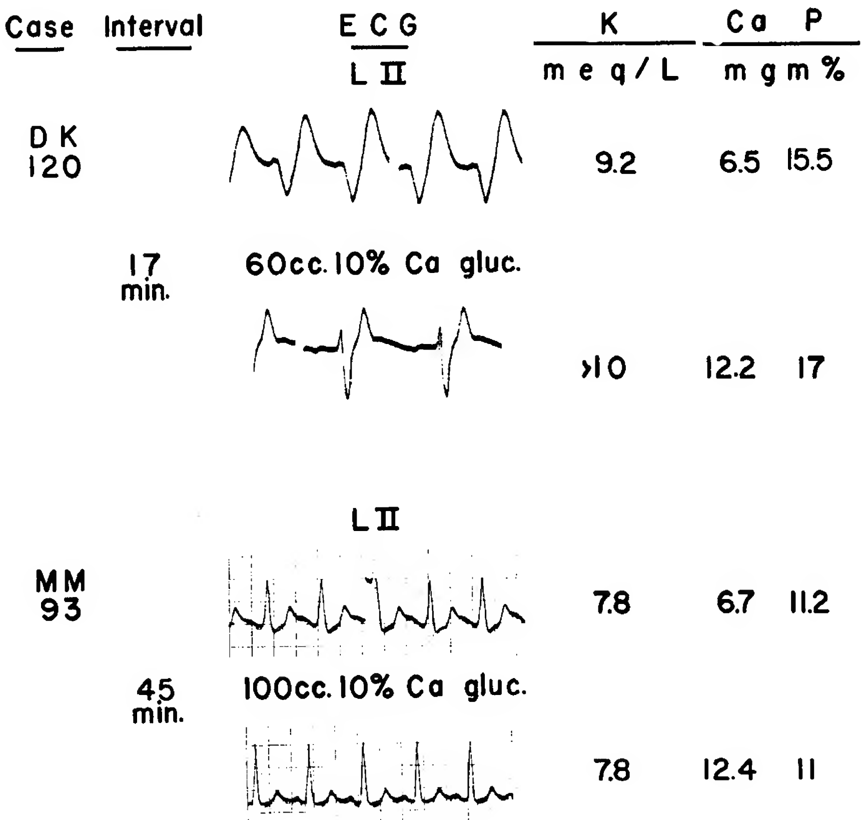

FIGURE 2.

The improv·:ment following a single intravenous injection of calcium is very transient. The plasma concentration of calcium falls quickly from the high level immediately after injection to the pre-injection level as governed by the phosphate concentration. Raising plasma calcium does not affect the level of plasma phosphate. Phosphate, unlike calcium, cannot be driven into the body repositories by such a maneuver. Intravenous glucose infusions will cause a slight reduction in plasma phosphate, but not enough to allow a rise in plasma calcium sufficient to antagonize potassium. Short of hemodialysis, the only effective way to maintain a normal level of calcium in plasma which is high in phosphate is by continuous intravenous infusion of calcium.

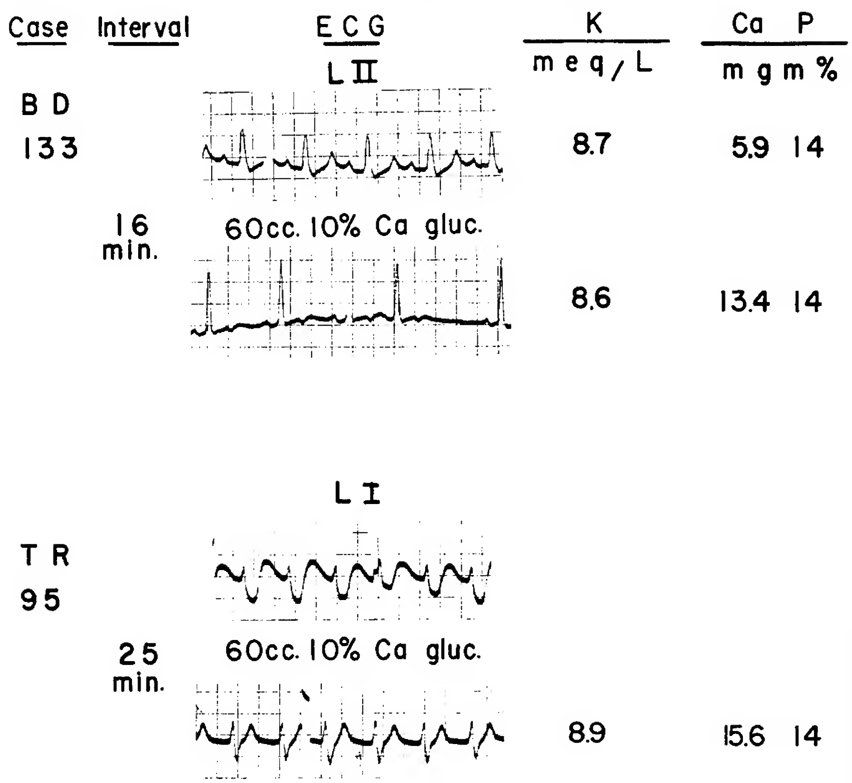

FIGURE 3.

The effect of calcium upon potassium toxicity is purely one of antagonism. The measurable level of potassium, as well as phosphate, is unaffected by raising plasma calcium. Once the calcium deficit is replaced, the electrocardiogram reflects the plasma level of potassium rather accurately, although still other factors, less apparent in our patients, have been shown to be influential (*5*, *7*, *9*).

Digitalis, which was rarely indicated in our patients, antagonizes potassium (*4*, *10*) in a manner similar to calcium. Digitalis and calcium appear to be additive in this respect, and great care should be used if both agents are administered to the same patient. There is particular danger if the excess potassium is suddenly removed by hemodialysis (*5*, *11*), allowing digitalis, enhanced by a high calcium concentration, to exert its toxicity without the opposing action of potassium.

Figure 4 demonstrates the electrocardiographic effects of relatively pure potassium excess in man. These tracings were selected from more than four hundred examples as most representative of the potassium level indicated when other known causes for abnormality were not present.

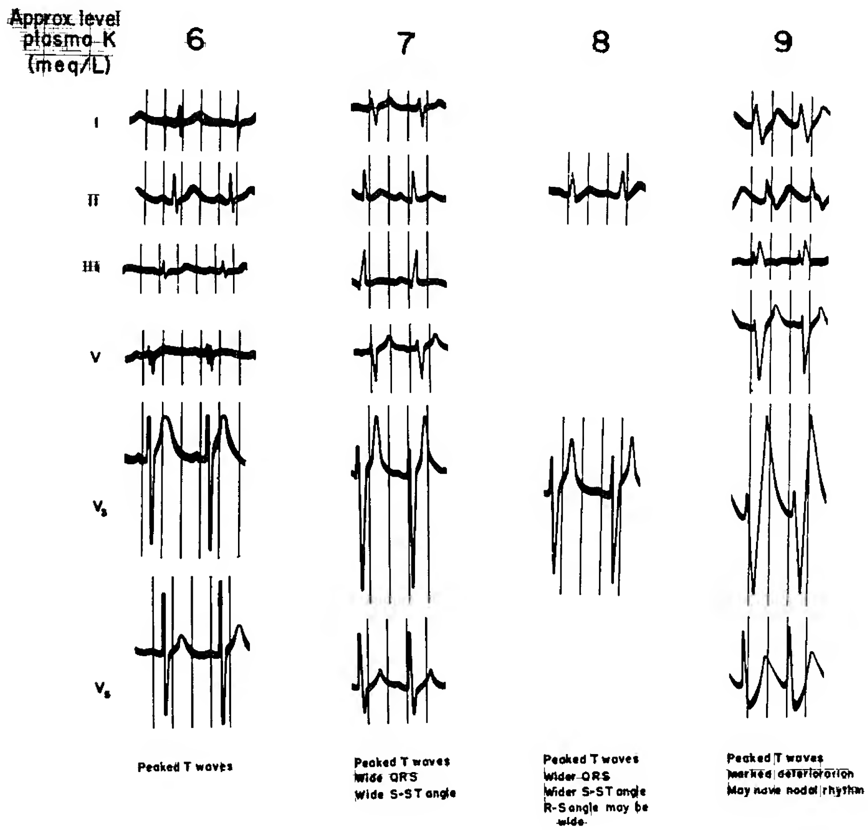

FIGURE 4.

Small excesses of potassium produce no abnormality except elevation and peaking of the T waves, best seen in the precordial leads. As plasma potassium increases further, the T wave abnormalities progress in the precordial leads and become obvious in the limb leads, but they have no quantitative significance in severe hyperpotassemia. Progressive changes in the QRS complex, best seen in the limb leads, are much more ominous. In the limb leads the angle between the S wave and the ST segment widens and encroaches upon the horizontal component of the ST segment until it is obliterated. P waves disappear; the T waves diminish in height and become rounded at the top; and finally, the R–S angle increases, and the smooth biphasic curves resemble a sine wave.

When the mild intoxication indicated by T wave abnormality only, suddenly progresses to the severe intoxication indicated by QRS widening, it usually is the result of a fall in plasma calcium. Infusion of calcium should cause instant reversion of the tracing to its former

degree of abnormality. If calcium does not produce an immediate effect, this indicates that the plasma potassium level has increased. Sudden rises in plasma potassium occur during oliguria when tissue cells are subjected to stress. Hemolysis, infection, or trauma may allow the release of all the potassium contained in the affected cells. Smaller amounts of potassium may leave cells temporarily in hypoxic states, only to be recovered by the cells when normalcy is restored. Hypoxia from hypotension, convulsions, certain types of anesthesia, pulmonary edema and simple breath-holding have been observed to cause such a reversible shift of potassium (*5*). In our experience, a rapid increase in the electrocardiographic evidence of potassium intoxication which was not responsive to calcium invariably was associated with a rapid increase of plasma potassium together with one of the above conditions.

Progressive potassium intoxication was asymptomatic in our patients until it had reached the stage at which the electrocardiogram showed severe deterioration similar to that of the fourth tracing in figure 4. Patients who had symptoms with a less abnormal electrocardiogram were found to have other causes for their symptoms. Many of the disorders associated with hyperpotasemia, such as those noted above, produce severe symptoms. Correction of the basic condition relieved the symptoms in our patients, although there were many instances in which the plasma potassium was still greater than 8 mEq./L. and the electrocardiogram was appropriately abnormal. Patient D. K. had neither signs nor symptoms at the time of the tracings shown in figure 2. If one attempts to follow the course of the intoxication in this type of patient by changes in tendon reflexes, respiratory symptoms, or by any known means except electrocardiography or blood chemistry, the patient likely will be dead before corrective action can be taken.

Another ion which affects the behavior of potassium and should be employed in the practical management of potassium intoxication is sodium. Sodium and potassium are inversely related in the plasma of the oliguric patient. Raising the plasma sodium concentration causes a fall in plasma potassium concentration, and the electrocardiographic effects of potassium intoxication are modified. Figure 5 demonstrates the beneficial effect of infusions of sodium bicarbonate upon the plasma potassium concentration and the electrocardiogram. Figure 6 is a similar demonstration of the effects of sodium chloride. Potassium concentration is depressed as sodium concentration rises, independently of the other ions, indicating that the agent responsible for the change is sodium and not the anion. An alkaline salt of sodium is preferred, however, because the retention of organic acids

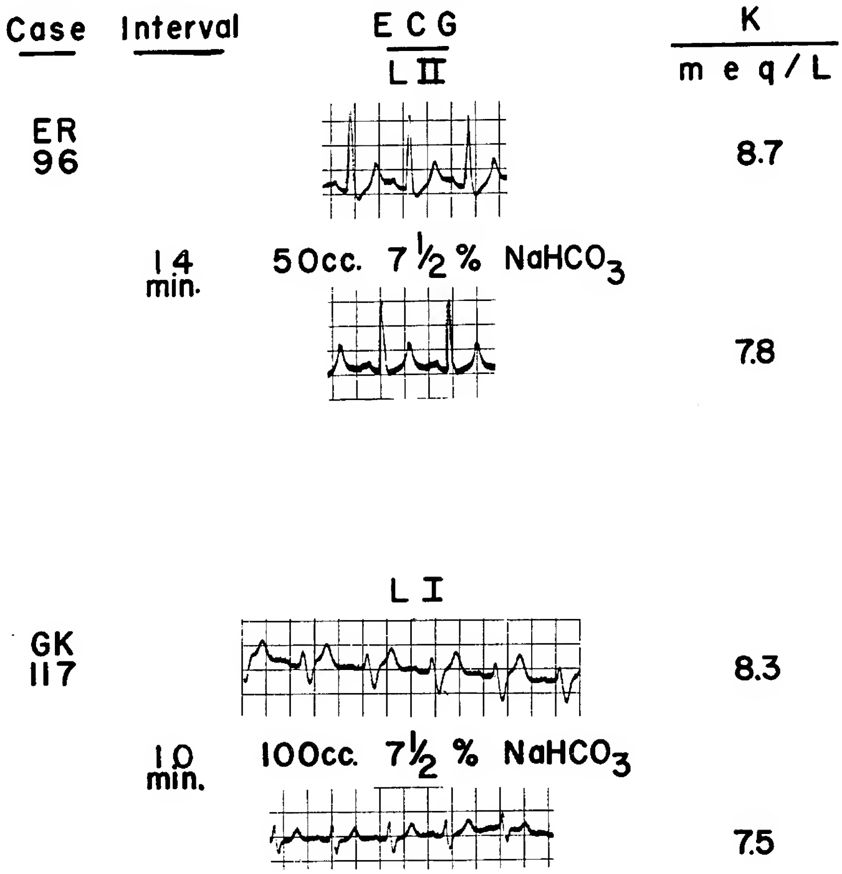

FIGURE 5.

regularly produces acidosis in these patients. The changes in the concentration of potassium and the other substances are not explained by dilution. Although tissue analyses were not performed, it is presumed that raising the plasma sodium concentration forces potassium back into cells.

The improvement in the electrocardiogram which followed a rise in plasma sodium and a fall in plasma potassium was sometimes greater than would be expected from the lower level of potassium. This suggests that sodium, in addition to depressing the plasma concentration of potassium, may also have some antagonistic effect similar to calcium. Figure 7 demonstrates the beneficial effect of raising plasma calcium from 5.9 to 7.8 mg. per 100 cc. and further improvement from additional calcium, followed by still further improvement from sodium chloride. The last tracing in this figure is almost normal, although the potassium concentration still is 7.2 mEq./liter. Obvi-

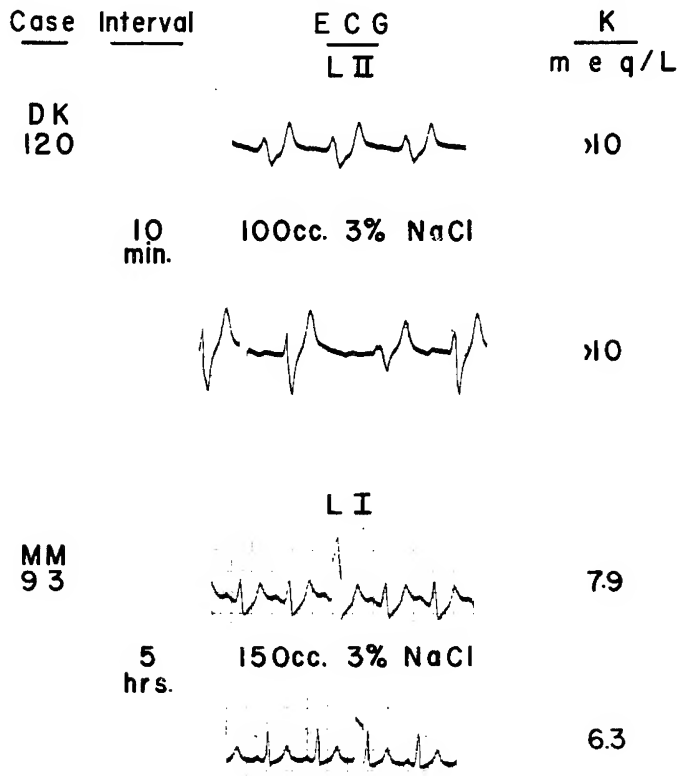

FIGURE 6.

ously, all of the factors influencing the response of the electrocardiogram to be given potassium concentration have not been considered. Hypertonic sodium infusions do, however, provide an effective and practical means for modifying potassium intoxication. Again it is emphasized that all of the patients in this series were young men without known previous cardiovascular disease, a fact which undoubtedly influenced their responses and should be considered if these methods are applied to dissimilar patients.

Another means for reducing plasma potassium concentration is the infusion of hypertonic glucose (*5*, *9*, *12*). The metabolism of glucose, which can be hastened with exogenous insulin, removes potassium and phosphate from the plasma. While calcium antagonizes the effects of potassium without changing the quantity present in the plasma, and sodium lowers plasma potassium concentration by some physico-chemical means, glucose carries potassium into cells by a more active process. As glycogen is formed, potassium, as well as phosphate, is incorporated into the carbohydrate complex, and this is an effective, though slower, method of controlling potassium intoxication. Re-

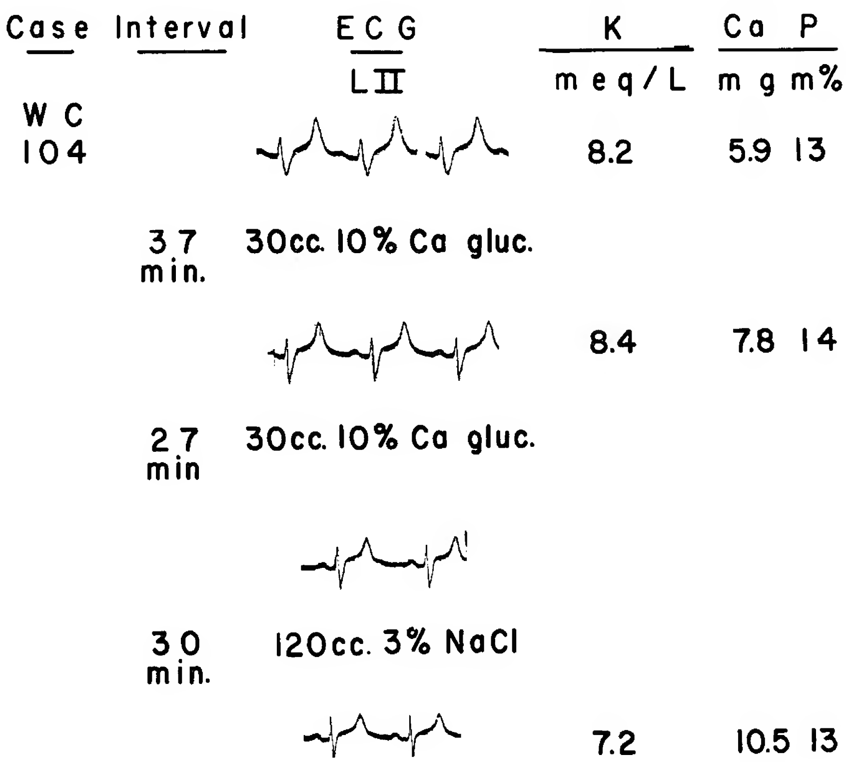

FIGURE 7.

sults similar to those of a glucose-insulin combination could be expected from the use of fructose, which has the advantage of not requiring insulin for its early metabolism, but this compound was not used.

If glucose is to be used effectively by the intravenous route, it should be given continuously. Intravenous glucose by intermittent injection causes a sharp spike in blood sugar level followed by hypoglycemia. The hypoglycemic period has the double disadvantage of failing to remove potassium during that period and of provoking glycolysis with further release of potassium to the plasma. Also, if nutrition is limited to intermittent intravenous feedings of glucose, the period between infusions is one of relative starvation, which is characterized by cell destruction and release of potassium.

Prescription

Based upon the above observations a standard solution was devised and found to be effective in controlling potassium intoxication for many days.

	cc.
Calcium gluconate 10 percent	100
Sodium bicarbonate 7½	50
Glucose 25 percent in H_2O (containing 50 u. regular insulin)	400
Normal saline (or ⅙ M sodium lactate)	Volume of output.

Give intravenously, preferably through a catheter, in a large vein at a constant rate of 25 cc. per hour.

Water-soluble vitamins should be added to this basic solution (*13*). Our patients received daily 2 gm. ascorbic acid, 50 mg. thiamine chloride, and 20 mg. vitamin K, but this vitamin prescription was chosen more in the interests of a concurrent study of wound healing and is not necessarily optimal.

If the laboratory can provide frequent determinations of plasma sodium, the sodium content of the fluid should be varied to maintain a plasma level of approximately 140 mEq./L. If not, the amount suggested can be given empirically without fear. The only complication arising from over-shooting the desired concentration is aggravation of thirst. This is uncomfortable for the patient, and if he is allowed excess water he may provoke pulmonary edema. None of the dire effects attributed to sodium administration (*14*) were observed in these patients, and it would appear that it is not the sodium alone but the excess water which may accompany it which is dangerous. In patients who are older or who have cardiovascular disease, there may be additional hazards associated with a high plasma sodium level. It is unlikely, however, that the dosage recommended would have adverse effects. A more likely source of harm is overhydration, and the necessity for water restriction must be kept constantly in mind.

If the laboratory can provide frequent determinations of plasma potassium, and it is not elevated, the calcium content of the fluid should be unnecessary. The purpose of the calcium in the infusion is to antagonize an elevated plasma potassium. If the potassium is not elevated, it follows that additional calcium is not needed for this purpose. The only other reason for giving calcium would be to prevent tetany if plasma calcium were depressed. However, in this type of patient plasma calcium is not depressed unless potassium is elevated, because the factor which causes hypocalcemia is an elevation of plasma phosphate, and phosphate rises at the same time as potassium. Therefore, calcium should be added to the infusion only if plasma potassium is elevated. If the laboratory is unable to provide frequent determinations of potassium, the electrocardiographic changes noted are sufficiently specific to guide logical therapy.

The constituent chemicals of the basic solution should be tailored for the individual patient when possible. If an item is omitted, its volume should be replaced by a normal solution or distilled water.

Ion Exchange Resins

Ion exchange resins are effective agents for the withdrawal of potassium from the plasma into the gut under certain circumstances (*15*). In this series of patients, however, those whose potassium was highest were unable to take anything by mouth. Rectal installation of resins was attempted repeatedly, but such intractable concretions were formed that the amount of water necessary to remove them caused water absorption and overhydration. An attempt was made to contain resins in a silk tube which could be inserted and extracted from the rectum mechanically, but the procedure was very painful for the patient. Also, effective exchange occurred only at the surface of the resin bolus, even when a silk tube of only 5 mm. diameter was used, and only 7mEq. of potassium was extracted by 30 grams of resin left in the rectum for 24 hours. It was intended to utilize a colostomy for this method but a suitable patient was not found. The impression was gained that resins would not be more effective than intravenous therapy as discussed.

Artificial kidney dialysis is the most definitive treatment known for removing potassium. Dialysis for hyperpotassemia alone is, in our experience, rarely indicated. Recommendations pertinent to this point are offered in section B, 2: Clinical Uremia. The author has had no experience with other methods for dialysis.

B. *Less Urgent Problems*

1. *Nutrition.* Principally fat and carbohydrate are recommended during the oliguric phase of acute uremia because of the potential toxicity of protein (*4, 16*). Maximal caloric intake is desirable to prevent the patient from burning his own tissues to supply his caloric needs, but the exact quantity of fat or carbohydrate necessary is unknown. Various high-calorie mixtures, such as olive oil and glucose, frozen butter balls, and commercial fat emulsion preparations, were given by mouth and by gastric and duodenal tube. Unfortunately, the patients who needed it most were nauseated by any of the forms of enteral feeding. Intravenous fat was not used in these patients because a satisfactory preparation was not available (*17*). Caloric intake, in the main, was limited to intravenous glucose, which was administered as outlined in the previous section. This is far from ideal but will sustain the patient. Current studies with newer anti-emetic drugs offer hope for successful oral or tube feeding.

2. *Clinical Uremia.* After a number of days of oliguria, in this series 5 to 8 days, the patient develops the syndrome of clinical uremia. He gradually becomes lethargic and shows evidence of mental torpor, yet his extremities are tremulous and hyperreflexic. The nausea,

which may have been present for days, now becomes active vomiting and retching. Intractable hiccups are usual. These clinical manifestations first appeared in our patients when plasma NPN was about 250 mg. per 100 cc. The consistency with which this figure was associated with the clinical findings was remarkable, and it came to be useful in allowing one to predict from an NPN value of, say, 200 mg. per 100 cc., that the patient would be symptomatic the following day.

At this juncture artificial kidney dialysis is strongly indicated. Six hours of dialysis will produce dramatic relief of symptoms as well as restoration of electrolyte balance. It does nothing for renal function, of course, but it clears the plasma of those substances which normally would have been excreted in the urine. The patient is then ready to start anew on his course of uremia, and if he does not diurese within several days, dialysis should be repeated and repeated again each time he becomes symptomatic until renal function is recovered. Dialysis was performed one or more times in 27 of our 48 patients. Fourteen were dialyzed once, 6 were dialyzed twice, and 7 were dialyzed 3 times.

It is important to recognize the syndrome of clinical uremia and to know when to expect it, because similar signs and symptoms can be produced by hypotension or sepsis. In our patients with renal insufficiency the NPN rose gradually to the critical level of 250 mg. per 100 cc. over a period of about a week. No patient attained this level or had symptoms of uremia before the fifth day of oliguria, and the average was later. When symptoms appeared, dialysis usually was performed and the symptoms disappeared. If dialysis was not performed, the symptoms progressed gradually, and 2 or 3 days elapsed before such threatening clinical manifestations as coma, convulsions and pericarditis appeared. In prerenal azotemia secondary to shock or sepsis, symptoms appeared at any time, usually within 1 or 2 days, and the symptoms were totally unrelated to the NPN level. The onset often was abrupt and the progression rapid. Dialysis was quite successful in restoring chemical balance but produced no beneficial effect upon the clinical manifestations. The rate at which plasma potassium and phosphate rose following dialysis also was quite different in these patients. Within a day, or even a few hours, of a normal post-dialysis level, great increment of potassium and phosphate were again found in the plasma. The condition which produced the symptoms was still present and it was associated with devitalization of tissue, which gave up its intracellular materials to the plasma. Dialysis, therefore, was virtually useless and the time lost in this procedure should have been spent in treating the basic condition of the patient.

The measures outlined for the treatment of potassium intoxication were effective, in our patients without necrotic tissue, for the period

prior to the appearance of clinical uremia. In some cases, dialysis was avoided altogether because diuresis occurred before clinical uremia appeared, and in others fewer dialyses were necessary. In the presence of clinical uremia, no attempt was made to control potassium further by medical means, because the dialysis which was otherwise indicated was superbly effective in removing potassium.

In an area where an artificial kidney is not available, the medical management of potassium intoxication may save the patient's life for the moment but should be used with a view to providing time for transport to a renal center. Where an artificial kidney is available, this method will allow dialyses to be performed on a reasonable schedule for clinical uremia only and should eliminate the emergency dialyses for potassium intoxication.

3. *Anemia and Hemorrhage.* Of the various causes for anemia and hemorrhage in post-traumatic renal insufficiency, the only one studied in this series of patients was the severe purpura similar to that seen in chronic uremia. Bleeding into the skin, nasopharynx and bowel appeared after 12 to 15 days and was related only to the duration, not the severity, of the uremia. Unlike the other manifestations of uremia, the hemorrhagic tendency was entirely unaffected by artificial kidney dialysis or by diuresis. To the contrary, the most severe bleeding in our series occurred several days after the onset of diuresis. The only positive temporal relationship was the cessation of bleeding with the resumption of normal diet. However, the absence of hemorrhagic diathesis during pure starvation discourages speculation on this point.

A search for the cause of the bleeding revealed no intrinsic clotting defect, only capillary fragility. The condition was unrelated to abnormality of plasma electrolytes and was unaffected by vitamins C or K or fresh blood transfusions. The replacement of the blood lost was considered desirable, yet transfusions were feared because a minor reaction might have exaggerated significance in a patient so ill. Nevertheless, small transfusions, 200 to 300 cc. daily, were given regularly without apparent harmful effect.

The presence of bleeding from whatever cause was originally considered a contraindication to artificial kidney dialysis, because of the necessity for heparinization before and during the procedure. On several occasions, however, dialysis was performed as a life-saving procedure on patients who were bleeding. During the procedure large quantities of blood were available for immediate use if bleeding should be aggravated, and following the neutralization of heparin with protamine at the end of the procedure, packed erythrocytes were given. No alarming bleeding occurred, and so it became the practice to dialyze any patient who had an indication regardless of hemor-

rhagic tendencies. The risk of dialysis in the presence of hemorrhage was considered to be less than the risk of the complications of uremia if dialysis were withheld, and subsequent experience supported this view.

4. *Infection and Antibiotics.* The specific infections encountered in these battle wounds (*18*) will not be reviewed here. In general, their successful management was dependent mainly upon thorough and frequent débridement. The amount of devitalized tissue and infection which may be acceptable in a patient with normal renal function may be lethal in the oliguric patient. Small amounts of tissue, particularly muscle, contain sufficient potassium to kill if it is released into plasma which is not being cleared by the kidney. Removal of such tissue must be prompt and thorough, and the approach must be much more radical than is customary with good surgeons. If the point at which devitalized tissue merges with normal tissue is not apparent to the surgeon, he should débride further. Excessive débridement may cost the patient precious tissue, but inadequate débridement may cost his life.

Remnants of devitalized tissue usually can be suspected if the plasma potassium and phosphate are inordinately high with respect to NPN. When the measures for controlling potassium outlined in Section A, 2 are employed, potassium does not rise as rapidly as it would if untreated. Plasma phosphate, however, is little affected by such measures and it is a useful index of the presence of necrosis. A plasma P/NPN ratio in excess of 0.06 indicated severe muscle destruction in our patients, and on several occasions deep necrosis underlying a wound with a clean surface was first suspected from this relationship (*19*).

In devitalized tissue antibiotics cannot be relied upon to control infection. Also, the proper methods for administration of antibiotics have not been clarified. The principal route for excretion of antibiotics is the urine, and during oliguria tremendous concentrations accumulate in the blood if usual doses are given. The importance of this fact was not investigated in our patients, but recent reports of serious toxicity from certain antibiotics require that great caution be employed (*20*).

The systemic infection most often seen in this type of patient is pneumonia. This complication is particularly apt to occur if the syndrome of clinical uremia is present and is not interrupted by hemodialysis. The hazard of pneumonia was combatted in our patients by deep-breathing exercises, voluntary coughing, frequent turning and good general nursing care. Patients whose cooperation was doubtful because of associated wounds or illnesses were placed up on Stryker frames where turning and drainage could be assured.

The diagnosis of oliguria automatically puts a patient into a group with a poor prognosis, although the renal lesion itself is usually reversible. The onset of infection may well be enough additional insult to cause a death which would not otherwise have occurred. The seriousness and the potential reversibility of the illness demand that no effort be spared in preventing or treating the complication of infection.

5. *Salt Wasting during Diuresis.* The onset of diuresis was arbitrarily defined in our patients as the day on which urine volume exceeded 1 liter. Once this volume was reached, the output increased rapidly, often 100 percent or more on successive days until a peak volume of 3 to 6 liters was attained. As the urine volume increased, the urinary concentration of nonprotein nitrogen, sodium, potassium and phosphate changed very little, and the total output of salts reached high values within 1 or 2 days. At this stage the kidneys excrete salts wantonly, without regard for the body's needs. Fortunately, appetite and food tolerance have now returned and salt depletion is partially offset by food intake. Daily supplements of sodium and potassium, however, must be added to prevent serious depletion. Sodium chloride 4 to 6 gm. and potassium chloride 1 to 2 gm. added to a regular diet daily for about a week were found to be adequate. Fluids were administered ad lib., without noticeable aberrations of fluid balance.

IV. *Summary*

Recommendations based upon experience with 48 patients with acute post-traumatic renal insufficiency and 11 patients with mimicking conditions have been presented.

The diagnosis of renal insufficiency is justified when a patient without hypotension, dehydration or urinary tract obstruction excretes less than 500 cc. of urine per 24 hours. Symptoms which appear within the first 2 days are not the result of uremia but commonly arise from incomplete resuscitation, incomplete débridement, or sepsis. If the surgical problems are controlled, haste in transfer to a renal center is unnecessary.

Management of renal failure consists of restriction of total fluid intake to 500 to 800 cc. plus the obvious output per 24 hours; emergency control of potassium intoxication by intravenous infusions of calcium salts; continued control of hyperpotassemia by maintenance of a normal level of plasma sodium and the continuous infusion of hypertonic glucose with insulin; maintenance of maximal caloric intake with protein-free, potassium-free foods or carbohydrate infusions (within the limits of the fluid balance); control of clinical uremia by hemodialysis; maintenance of the hematocrit at 30 percent or more;

control of infection by good nursing care, frequent dressing changes, radical débridement and judicious use of antibiotics; and prevention of salt deficits during diuresis by administration of sodium and potassium.

Application of this system of management should prevent deaths from renal failure and provide surgeons with patients better able to withstand definitive treatment of the primary disorders.

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WOUND HEALING IN PATIENTS WITH SEVERE BATTLE WOUNDS AND RENAL DYSFUNCTION*

STANLEY M. LEVENSON, M. D.

I am going to restrict my remarks this morning to a discussion of some of the problems of wound healing encountered among a group of patients similar to those just described by Major Meroney—that is, patients with extensive wounds and serious renal dysfunction. When I arrived in Japan and Korea in January, 1953, it was generally considered by most of the Chiefs of Surgery and Surgical Consultants that delays in wound healing were infrequent among patients with battle injuries except among those who also had acute renal failure. The physicians at the Renal Center were also of the firm opinion that wound healing was impaired in these latter patients and that wound complications contributed significantly to their high mortality (50–60 percent). To obtain some specific data in this regard, all the clinical and autopsy records of the 70 patients admitted to the Renal Center from its opening in the spring of 1952 through the middle of February 1953 were reviewed in collaboration with Captain Paul Teschan.

The records of 21 of the patients were inadequate for analysis. Seven of the remaining 49 records were discarded because of very short survival times of the patients. Forty-two records, then, were deemed adequate for analysis. However, it should be mentioned that the progress notes were written by internists, that the records were not specifically directed towards problems of wound healing, that bacteriologic studies were inadequate and that only casual attention was paid to the wounds at autopsy.

Among the 42 patients whose records were analyzed, gross impairment of wound healing was noted in 31. The term "impairment" is used in a broad sense and is not meant to imply a specific or nonspecific defect in wound healing. Mortality among the patients with impaired wound healing was high; wound complications were among the more frequent and more important causes of death (table 1).

Two general types of wounds were present in these patients—wounds closed primarily, such as laparotomy incisions, and wounds left open after débridement. The time of secondary closure of the

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Table 1. Wound Healing in Patients with Renal Dysfunction

Group	Number of patients	Number of deaths	Average day of death
Patients with unimpaired wound healing	11	0	----------
Patients with impaired wound healing	31	16	15

latter wounds was delayed in patients with renal failure. In patients without renal dysfunction, such wounds were usually closed 5 to 10 days after injury. Patients with renal dysfunction were often at their sickest during this time and secondary closure was rarely carried out during this period. Consequently, the wounds of patients with renal dysfunction remained open for significantly longer periods of time than in patients without renal dysfunction. Similarly it should be pointed out that these patients were among the most seriously injured and usually were in severe shock in the early period after injury. Consequently, it is possible that under these circumstances débridement might have been inadequate in certain of these patients. There is also some question as to the quality of the later surgical care of these patients.

Among the 31 patients with gross impairment of wound healing, the open wounds were often described as indolent, with granulation tissue absent, or when present, soggy and edematous. In a number of these patients, progressive necrosis and suppuration of the wounds was described. I will not take time to show any pictures of such wounds, since you have already seen many illustrations of wounds just before and just after débridement and I am sure that the speakers this afternoon will present pictures of wounds in the later stages.

Among the 42 patients whose records were analyzed, there were 28 who had *laparotomies* (table 2). Six of these were in the group with unimpaired wound healing, and, as indicated by group classification, none of these wounds ruptured. Among the 31 patients with impaired wound healing, 22 had laparotomies. There were five abdominal wound *dehiscences* in this group. This is a high incidence of wound rupture and is apparently higher than occurred in patients with serious battle wounds but without renal dysfunction. However, this cannot

Table 2. Wound Healing in Patients with Renal Dysfunction

Group	Patients	Laparotomies	Dehiscences
Patients with unimpaired wound healing	11	6	0
Patients with impaired wound healing	31	22	5

be stated with certainty at this time, since no overall systematic tabulation of wound healing among the battle casualties of the Korean conflict has been made. In this regard, there has been considerable difference of opinion among the surgical chiefs and consultants as to the incidence of postoperative hernias in laparotomized patients; opinions have varied from "very few" to "very many."

The actual incidence of impaired healing of laparotomy wounds among the patients with renal dysfunction may well be higher than indicated by the figures of wound ruptures. Once it appeared that these patients might be having difficulty in wound healing, sutures were left in for many weeks. Under this circumstance, the wounds of some patients were described as held together only by the retention sutures, with no apparent healing having occurred. Similarly, a number of patients whose laparotomy wounds looked good and appeared to be healing normally came to autopsy 7 or more days after injury. No special examination of the abdominal incision was made routinely, but in an occasional instance when the sutures were removed or an attempt was made to biopsy the wound, the wound fell apart.

Among the five patients with actual wound rupture, a possible local reason for the dehiscence was apparent in three (table 3). In one, dehiscence occurred on the ninth postoperative day and examination revealed an extensive hematoma in the wound; in another, dehiscence occurred on the tenth postoperative day—peritonitis and an infected abdominal wound were present; in the third, dehiscence occurred on the fourteenth day—severe peritonitis with ascites was present. No specific local reason for dehiscence was noted in the other two patients. In one of these two, dehiscence occurred on the eleventh day; in the other, on the sixteenth day. Disruption this late postoperatively is unusual and would suggest a definite delay in the healing process. At the time of the dehiscence, this last patient was emaciated. The abdominal wound was resutured and the patient lived for 9 more days. At autopsy, the resutured wound was described as follows: "There is a longitudinal mid-line abdominal surgical incision measuring approximately 12 cm. in length around which radiate multiple

Table 3. Wound Healing in Patients with Renal Dysfunction, Dehiscences of Laparotomy Wounds

Number of patients with laparotomies	28.
Number of dehiscences	5.
Apparent "local cause" for dehiscence	3.
Peritonitis $\bar{c}$ ascites	1; 14th day.
Hematoma	1; 10th day.
Wound infection	1; 9th day.
No apparent "local cause" for dehiscence	2; 11th and 16th days.

superficial draining sinuses measuring 2 cm. in length. Granulation tissue lines the upper half of the surgical incision which presents an opening measuring 5 x 1 cm. The base of this sinus tract is lined by dense yellow-red granulation tissue. Wire sutures support the incision." Two more of the patients whose ruptured laparotomy wounds were resutured died, but the wounds were not specifically examined at autopsy.

Two of the five patients with dehiscences lived (table 4). The resutured wound apparently healed uneventfully in the patient whose dehiscence had presumably been secondary to the hematoma. The other patient who survived was the patient whose wound had ruptured 11 days postoperatively with no local cause for dehiscence being apparent. After resuturing, he developed peritonitis and intestinal obstruction. These complications were considered by those caring for the patient as subsequent to the dehiscence, rather than present before, and perhaps etiologically important for, the first dehiscence. A third laparotomy was performed on this patient through another incision 19 days after the resuturing of the first laparotomy wound. Localized intraperitoneal abscesses and obstructing adhesions were found. One week later, purulent material drained from the first and second abdominal incisions. Shortly thereafter, a fecal fistula appeared in the other abdominal incision. The patient had lost a considerable amount of weight (over 30 pounds) and was transferred to a general hospital in Japan for further therapy.

Table 4. Wound Healing in Patients with Renal Dysfunction.

Number of secondary sutures of dehisced laparotomy wounds	5
Number of patients surviving	2
"Normal" healing of resutured wound	1
"Abnormal" healing of resutured wound	1
Number of patients dying	3
"Abnormal" healing of resutured wound	1
Quality of wound healing unknown	2

A comparison between the two groups of patients (those patients with unimpaired wound healing versus those with impaired wound healing) was made to determine some of the factors which might have had some bearing on the observed differences in wound healing. It appears that those patients with impaired wound healing were in general the more seriously injured, the sicker, the more uremic, required more dialyses, had greater changes in water and electrolyte metabolism with associated edema and/or dehydration, lost more weight, had more severe infections, and showed a higher incidence of abnormal bleeding. The severity of anemia could not be adequately

estimated. In the majority of patients multiple factors were operative and presumably interrelated. Serious uremia, marked malnutrition and severe infection were the most frequent factors.

Severity of the Renal Dysfunction: Dialysis

Renal dysfunction was greater in the group with delayed wound healing. As you can see in table 5, the average time of diuresis among these latter patients was 12 days after injury as opposed to the average time of 5 days after injury of 10 of the 11 patients with unimpaired wound healing. In addition, 11 patients with impaired wound healing died 5 to 19 days after injury without ever diuresing. Similarly, whereas only 3 of the 11 patients with unimpaired wound healing had maximum levels of plasma nonprotein nitrogen over 275 mg. per 100 cc., two-thirds of the group with impaired healing had such high levels.

Table 5. Wound Healing in Patients with Renal Dysfunction

Group	Number of patients	Day of diuresis	Number of patients with maximum blood NPN over 275 mg. percent
Patients with unimpaired wound healing	10	5	2
	1	22	1
Patients with impaired wound healing	31	*12	21

*Includes 11 patients who died on the 5th to 19th days without ever diuresing.

Among the patients with apparently unimpaired wound healing, there was only one who required dialysis (table 6). This was a Korean soldier with wounds of the face and neck who developed a severe hemolytic reaction to a transfusion of 1,000 cc. of blood during his initial operative treatment. Following this, he developed oliguria and was transferred to the 11th Evacuation Hospital on the third post-injury day. During a prolonged period of oliguria (19 days) and uremia, three hemodialyses were performed. The neck and face

Table 6. Wound healing in Patients with Renal Dysfunction

Group	Number of patients	Number of patients dialyzed	Number of dialyses
Patients with unimpaired wound healing	10	0	0
	1	1	3
Patients with impaired wound healing	31	24	56

wounds showed apparently normal and entirely satisfactory healing. These wounds were in well vascularized areas in which healing is usually favorable.

Among the 31 patients with apparently impaired wound healing, there were 24 who required dialyses. The average number of dialyses in these patients was about 2.3. At the moment, there is no specific evidence to implicate the dialysis procedure *per se* as an important factor in the pathogenesis of the impaired wound healing—e. g., there were a number of patients with impaired wound healing who did not have dialyses. The fact that many more patients in the impaired healing group were dialyzed than in the group with unimpaired healing may be simply indicative of the severity of the hyperkalemia and uremia of the former group. On the other hand, one cannot definitely rule out the dialysis procedure itself as an important factor—e. g., what is the washout of the water-soluble vitamins (specifically ascorbic acid) during dialysis?

Malnutrition. Weight loss is a constant feature of the patients with serious injuries and renal dysfunction. The average weight loss was greater among those patients with impaired wound healing. Weight losses of 20 to 25 pounds were common among the group with unimpaired healing, while among the group with impaired healing 30- to 40-pound weight loss was not uncommon (table 7). What the weight loss specifically represents in terms of body tissue, water, fat, etc., is not known. The first weights recorded are those on admission of the patient to the 11th Evacuation Hospital. At this time, many of the patients were presumably waterlogged. Insensible water loss must be an important factor in the weight loss of these patients, since prolonged hyperpnea is a common feature. However, examination of metabolic data available in a few patients reveals a large nitrogen "loss" (i. e., NPN accumulation in the body water, NPN lost by dialysis, and NPN excreted in the urine). In one patient, this amounted to about 45 gm. N per day, which represents the daily breakdown of about 2.5 pounds of body tissue (excluding fat).

Table 7. Wound Healing in Patients with Renal Dysfunction

Group	Number of patients	Weight loss (pounds)
Patients with unimpaired wound healing	11	20–30
Patients with impaired wound healing	31	30–45

Infection. Infection was one of the major complications among the severely injured patients with renal dysfunction. I am not going to

spend much time on this aspect of the problem because it is discussed in three other papers. However, I want to indicate some of the data which apply to this particular series of patients. Among the 31 patients with impaired wound healing, wound infection was almost universally present. Infection, either in the wound or elsewhere, is listed among the causes of death in all but 1 of the 16 patients in this group who died. Peritonitis is listed four times; intra-abdominal abscesses, six times; spreading infection of peripheral wounds, four times; severe bronchopneumonia, four times; septic infarcts (lung, kidney, etc.) twice, and empyema twice.

In view of certain observations of an increased migration of bacteria across the intestinal wall in uremic dogs, the autopsy records were examined to see whether there have been any instances of peritonitis in the absence of intra-abdominal injury. No instance of peritonitis in the absence of a previous laparotomy was found. There were one or two instances of mild peritoneal infection in patients with a "negative" laparotomy, but the possibility of undiscovered intra-abdominal injury cannot be ruled out.

It was evident from reviewing the records of these patients that wound healing was a very important complication among the patients with renal dysfunction. It would appear that in the majority of the patients multiple factors were operative and presumably interrelated. However, it was apparent that with the data at hand, no specific conclusion as to the relative importance, or interrelationship, of the various factors could be made. Studies to define the problem specifically and thereby lead to improved prophylaxis and therapy were indicated. A start in certain of these will be presented by other speakers later today.

Some of the problems which needed (and still need) solution are as follows:

1. What is the course of normal wound healing (open wounds, sutured wounds, etc.) in man?

There is a paucity of detailed correlated (clinical, histologic, bacteriologic, etc.) information regarding wound healing in man. There are very few controlled clinical studies and none specifically applicable to the problems at hand. Most of the specific data regarding wound healing have been obtained in animals. The difference in wound healing among various species makes it imperative that caution be used in directly relating the results of animal experiments to man.

2. What is the effect of the magnitude of injury on wound healing, and, if an effect is present, to what factors may it be attributed? What is the clinical significance of the "catabolic" reaction to injury?

Very few objective data concerning the physiological and clinical sequelae directly attributable to the early "catabolic" reaction to in-

jury are available. There are conflicting opinions as to the harm resulting from this period, and depending on the viewpoint taken, attempts are or are not made to reverse the process. Much of the conflict is due to the *lack of objective indices* of the benefits, or lack of benefits, of mitigating the early metabolic disturbances.

The injured man must heal his wounds for successful recovery; systematic observations of the healing of wounds, traumatic, operative and experimental, would provide objective evidence in one important area as to the significance of the "catabolic" period. For example, the seriously injured individual acts biochemically like a scorbutic in the first days and well after injury; does he also act like a scorbutic in regard to the healing of his wounds? Further, the intensity of the urinary nitrogen loss following injury may be decreased by the injection of testosterone propionate. Since the anabolic effects of testosterone are different for different tissues, what does the decrease in urinary nitrogen excretion mean in terms of wound healing?

It has been postulated by some that no attempt be made to reverse the "catabolic" reaction because it is a "defense mechanism" to supply metabolites to the injured area. There is no concrete evidence to support this. There is no reason, at the moment, to assume that the injured area is necessarily more proficient than other tissues in "utilizing" the circulating metabolites. We have recently studied the healing of experimental laparotomy wounds in normal and severely burned rats. Observations of the gross appearances, tensile strengths and histologic features of the incisions were made. The healing of laparotomy wounds in the burned rats was significantly different from that in the unburned controls. Epithelization was not affected, but there was a definite delay in the formation of granulation tissue in the incisional wounds of the burned animals with a lag in the appearance and maturation of the fibroblasts and the ground substance. The eventual number and amount of these two elements, however, did not appear to be affected, and abundant granulation formed in the wounds of the burned rats in time. In some of the burned rats the wound area appeared somewhat more edematous than that of the controls. The incidence of wound infection was also somewhat higher among the burned animals.

3. Is there a specific effect (direct or indirect) of renal dysfunction on wound healing? Or are the delays due to associated abnormalties in nutrition, water balance, ability to resist infection, etc.?

Various degrees of renal dysfunction will be produced experimentally in a number of different ways. Emphasis will be directed toward simulating the clinical problem of "lower nephron nephrosis." The course of wound healing in animals with renal dysfunction, untreated and treated in a variety of ways, including dialysis, will be studied.

Observations on local and systemic infection and various immune responses will be made. These data will be correlated with various nutritional and metabolic measurements.

4. What is the basis for the apparent high incidence of wound infection in the patients with renal dysfunction?

It is well recognized that *infection*, when present, is a detriment to wound healing. A careful study of wound infection is important, not only in the early post-injury period, but throughout the healing period. Why is wound infection so frequent, and so serious, in the severely wounded patient with renal dysfunction? Does the malnutrition predispose to wound infection, or does the wound infection accelerate the development of malnutrition? What is the ability of the seriously injured man in regard to antibacterial defense? Following simple starvation, lymphoid tissue is markedly depleted; chronically protein-depleted rats are unable to synthesize certain antibodies as well as normally nourished animals. What is the ability of the seriously wounded man who is on a totally inadequate diet to form antibodies? What is the efficiency of phagocytosis, etc., in such an individual? Further, most of these patients may be on various antibiotics, certain of which, when given orally, may lead to nutritional disturbances under certain circumstances.

5. What are the effects of *plasma* substitutes and/or *anemia* on wound healing?

It would appear that in many instances a combination of whole blood and dextran (or some other plasma substitute) may be satisfactory for early replacement therapy of shock. Under this circumstance, a certain degree of *anemia* will be present at the time the patient is evacuated further to the rear. Ordinarily, surgeons feel that anemia *per se* is detrimental to wound healing and will be inclined to transfuse such patients prior to secondary closure, etc. Is this a necessary or wise procedure (considering possible shortage of blood, transfusion reactions, etc.)? Is there a direct effect of anemia on wound healing or is there, perhaps, an indirect effect? Is hemoglobin a high-priority protein in the severely injured patient during the catabolic period and, if so, will protein be diverted from the healing wound to form hemoglobin if anemia is present? No conclusive data on the influence of anemia on wound healing in man are available; the data in animals are controversial.

What is the effect of plasma expanders *per se* on wound healing? Data in this regard are meager. Rhoads and his co-workers observed that whereas there was a delay in the healing of abdominal wounds in hypoproteinemic edematous dogs, there was no delay in hypoproteinemic dogs given acacia intravenously in amounts sufficient to eliminate the edema, but which, at the same time, accentuated the de-

crease in plasma protein concentration. Thorsen has reported no delay in the healing of incisional wounds in rabbits given dextran. We have observed no gross abnormalities in the healing of burns in patients who have received large amounts of dextran, but no special studies of the wounds were made.

6. What are the optimal prophylactic and therapeutic nutritional (dietary, hormonal, etc.) regimens for the wounded patient with or without renal dysfunction?

If the period of metabolic derangement persists, progressive nutritional deterioration with its consequent well known ill effects occurs. What is the optimal nutritional (dietary, hormonal, etc.) care of these individuals? I will discuss this in detail in another paper.

Proposed Studies

From the foregoing it is evident that a study of the individual and his wounds directed toward a comprehensive correlation and evaluation of systemic and local phenomena is needed. Such a study will entail the use of a variety of technics, clinical, metabolic, bacteriologic and pathologic. The clinical studies should be supplemented by animal studies in a variety of species.

Some Factors in Wound Healing Requiring Control

- A. *Systemic Factors.*
    1. Extent and sites of wounds.
    2. Associated injuries (and/or illnesses).
    3. Circulatory system (shock, sludging, etc.).
    4. Metabolic and nutritional state (including anemia, antibiotics, all nutrients, etc.).
    5. Plasma substitutes (primary and secondary effects).
    6. Infection (including "resistance" of individual, etc.).
    7. Blood clotting mechanism.
- B. *Type of Wounds.*
    1. Contaminated wounds, débrided and secondarily sutured (including time of secondary suture).
    2. Contaminated wounds débrided and primarily closed.
    3. Clean, incised wounds closed primarily (including type of closure, etc.).
- C. *Local Factors.*
    1. Extent and sites of wounds (including surrounding and supporting tissues; proximity to joints; direction of wound relative to lines of stress, etc.).
    2. Blood supply (arterial and venous).
    3. Infection (including antibiotics, etc.).
    4. Wound edema or dehydration (local or systemic basis).

D. *Medical and Surgical Care.* The quality and types of medical and surgical care are, of course, of paramount importance, but will not be discussed in this paper.

In summary, this analysis of wound healing among patients with serious battle injuries and renal failure confirms the impressions of various physicans that wound complications were frequent and important in these patients. Further, the analysis has indicated the complexity of the problem, some possible interrelationships among various factors, and the need for concrete objective study, clinical and experimental.

Discussion

COLONEL HANSON. Stimulated by Dr. Levenson's visit to the Far East, a study of some of the problems of wound healing was undertaken by the research team in Korea in collaboration with the staff of the 406th Medical General Laboratory in Tokyo. Serial biopsy materials obtained from about 19 patients were examined and an attempt was made to evaluate certain histologic features such as the general state of healing as a whole, growth of capillaries, proliferation of fibroblasts, production of reticulum and collagen.

Some of the preliminary conclusions may be mentioned. I think that we can state that in the severely wounded casualty, the response to injury may be lessened in patients with marked renal failure, in cases where there is a diminished blood supply or local anemia, and in that group of cases where there has been a marked catabolic effect and severe weight loss. The wounds of such patients do not heal like those of the normal or less severely traumatized patients. However, we could not draw any conclusions as to mechanisms involved, but it is likely that many mechanisms, probably interrelated, are involved.

MAJOR BALCH. One thing Dr. Levenson did not bring out quite clearly enough in his presentation was the character of the surgical care of the patient whose records he reviewed. I was not at the Renal Center at the time those cases were studied, but I understand from others who were there that at the time the Renal Center was first set up, it was not properly realized that a full-time surgeon was needed in the care of these patients. Many of those patients were cared for surgically by the general surgical staff of the hospital. Now, those surgeons had other duties and responsibilities and they were frequently quite busy and could not come for many hours or, perhaps longer, to take care of the renal patients. So, evaluation of the complications that have been reported today, and I believe they are true complications, is complicated very much by the fact that it is likely that the surgical care was inadequate in those patients.

I would like to ask Colonel Hanson whether the factor of infection could be separated from delay in wound healing in the biopsy specimens?

Colonel Hanson. In those cases where there was massive wound infection, the factor of infection could be separated from delays in wound healing, but in cases where there was just minor infection, it was questionable whether these factors could be separated.

Dr. Howard. I wonder if one of the most important elements in the wound complications among these patients is their primary surgical care? We have by definition selected a group of patients who are critically injured, who are profoundly hypotensive and in whom the primary surgical care is quite likely to be compromised. I wonder if inadequate débridement or hasty closure of an abdominal wound, due to our efforts to salvage life at the moment, might not be reflecting itself in later wound complications?

Dr. Levenson. That is probably true, Dr. Howard, and I mentioned that briefly in my presentation. However, at present, most records I have seen are not adequate to enable objective evaluation of the adequacy of débridement. I think we all would assume that in many instances débridement was inadequate, and in a few instances foreign material (clothing, etc.) was found in secondary débridements.

I am glad that Major Balch made his comment regarding the questionable quality of the later surgical care of these patients. I meant to mention it, but inadvertently did not. In this regard I would like to make one additional comment. Cross-infection was one of the factors possibly important in the high incidence of wound infection among this group of patients. These patients were kept on a single ward and it was not possible to carry out, either on the ward, in the dressing or operating rooms, procedures which have been advocated for the prevention of cross-infections.

WEDNESDAY AFTERNOON SESSION

21 April 1954

MODERATOR

LIEUTENANT COLONEL EDWIN J. PULASKI, MC

THE BACTERIAL FLORA OF WOUNDS IN THE KOREAN WAR*

LIEUTENANT COLONEL ROBERT B. LINDBERG, MSC

The relation of wound infections to the bacterial population of war wounds has varied extensively during the period from World War I to the present. The classic battle problem of gas gangrene was relatively inconspicuous in the Korean war, at least during the major part of the conflict, which was fought over a relatively stable front. In the two preceding wars, principal pathogenic species of anaerobes included *Clostridium perfringens*, *novyi*, *septicum*, and *histolyticum*, while in the Korean war only one of these species, *Cl. perfringens*, was present in a high percentage of cases. Several conditions of contemporary warfare undoubtedly contributed to this altered bacteriologic picture. These included the extensive use of penicillin and the broad-spectrum antibiotics; rapid evacuation of the wounded; forward location of the Mobile Army Surgical Hospital, with consequent shortened time from wound to definitive treatment; prompt and more effective resuscitation; and radical débridement, frequently within 6 hours of wounding. The major part of data on bacteriology of wounds in the Korean war was obtained after the war had passed from its initial fluid phase to the situation of a static front. Hence the cases observed tended to have a more optimal time interval between wounding and treatment, with a consequent reduction in the bacterial population of the wounds as compared with those incurred during the initial phase of retreat and defense of the Pusan perimeter, as well as under the circumstances of retreat from the Yalu River after the Chinese intervention.

Studies of war wounds in World Wars I and II, including the studies of Weinberg and Seguin (*1*), Stock (*2*), MacLennan (*3*), and Smith (*4*), showed presence of a complex bacterial flora, with multiple species of *Clostridia* and aerobic organisms typically present. Their reports are chiefly of cases which had progressed to the stage of wound *infection*, in contrast to the situation in recent wounds in the Korean war. Here we were concerned mainly with contamination and early bacterial proliferation, before clinical evidence of infection

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appeared. Comparable studies of later wounds were made during the course of evacuation and treatment in Korea and Japan.

This report presents briefly the wound flora of battle injuries at three levels: first, those seen at the time of débridement at Army Surgical Hospitals, usually within 6 to 8 hours of wounding; second, those seen at the evacuation hospital, 24 to 72 hours post-wounding; and third, those seen at the general hospital level in Japan, 4 to 21 days after wounding. The bacteriology of wounds in cases necessitating amputation one week or more after wounding was also determined. The flora of local soil, clothing and the skin surface of line troops was observed for comparison with the flora of wounds. The aerobic flora of the wounds also was studied, and will be briefly summarized. Antibiotic sensitivity of Clostridia was determined, and the relationship of this sensitivity to blood and tissue levels of antibiotics in wounded men was observed.

Observations on Flora of Recent War Wounds

Wounded personnel from the east-central front (Mundung-ni) were studied during August and September, 1952, and from December 1952 to February 1953, with cultures of tissue samples collected during débridement at the 46th MASH.

The object was to determine the extent and nature of wound contamination during the first few hours postwounding. Infection was not a major problem at this brief time interval. Specimens were collected, placed in a modified Robertson's cooked meat medium,* and shipped to Japan for study. This holding medium offered an optimal means for transporting clostridial cultures with maximum survival of multiple species in a single sample. However, an occasional series of tissue samples were found to be negative for Clostridia despite gross contamination. Such results may have been due to undetected variations in the transport and enrichment medium, and these tissue cultures hence show fewer Clostridia than were undoubtedly present in the tissues at the time of debridement.

Principal emphasis was placed on study of wounds of the extremities. The object was to determine the flora present, without losing sight of the fact that presence of Clostridia in a wound does not of necessity connote anaerobic infection. In World War II over 50 percent of wounds were contaminated with Clostridia, yet only 1 percent to 2 percent of cases showed any clinical evidence of clostridial infection (*5*).

*The classical formula of an aqueous meat infusion with meat particles added was modified by the incorporation of a heart infusion in place of distilled water. pH was 7.4.

Findings in the two series of early wound cases were sufficiently disparate to make separate presentation of the results desirable.

During August and September, 1952, 94 tissue samples were collected from 33 patients, of whom 31 (94 percent) yielded Clostridia. Of the 94 tissue blocks, Clostridia were recovered from 63 (67 percent); 125 strains, including 19 species, were recovered. The total number of species of Clostridia recovered per patient was 4. An average of 2 strains of Clostridia were recovered from each positive tissue block. The average time elapsing between injury and obtaining of tissue sample was 4½ hours. The relative extent of tissue destruction was related to the extent of clostridial involvement: Artillery wounds were 88 percent positive and harbored an average 3 species per patient. Mortar and grenade wounds were 65 percent positive for Clostridia and harbored an average of 6 species per patient. Small arms fire produced wounds of which 55 percent showed Clostridia with an average of 1.3 species per patient. The incidence of Clostridia in tissues and in cases of 28 patients of this series is shown in table 1. It will be seen that *Cl. sporogenes* was the predominant strain in terms of cases and of tissue samples studied. The principal pathogenic species was *Cl. perfringens*, in 46.4 percent of cases, and

Table 1. Incidence of Clostridia in Tissues of 28 Patients with Recent Wounds

Clostridium species	Number of cases in which found	Percent of 28 cases positive for Clostridia	Total number of tissues examined in cases positive for sporogenes	Number of tissues positive of all positive cases	Percent of total tissues positive from positive cases
Sporogenes	18	64. 2	78	40	51. 2
Perfringens	13	46. 4	58	29	50
Bifermentans	10	35. 7	57	16	28
Novyi	7	25	24	10	41. 6
Multifermentans	7	25	37	11	29. 7
Paraputrificum	5	17. 8	16	5	31. 2
Sordelli	3	10. 7	9	4	44. 4
Lentoputrescens	3	10. 7	8	3	37. 5
Tertium	3	10. 7	6	3	50
Tetanomorphum	3	10. 7	15	4	26. 6
Butyricum	2	7. 1	7	3	42. 8
Tetani	2	7. 1	14	3	21. 4
Aerofoetidum	2	7. 1	5	2	40
Carnis	1	3. 9	2	1	50
Capitovale	1	3. 9	4	1	25
Cochlearium	1	3. 9	3	1	33
Putrefaciens	1	3. 9	3	1	33
Sphenoides	1	3. 9	4	1	25
Histolyticum	1	3. 9	2	1	50

in 50 percent of the tissues. *Cl. novyi* was present in 25 percent of this brief series of cases. No other pathogenic species appeared in large numbers.

Blood cultures taken on 15 severely wounded men yielded an unexpectedly high proportion of anaerobes: 11 were positive, with 4 species and 19 strains of Clostridia recovered. Although bacteremia due to Clostridia had been observed previously, this proportion was deemed unusually high. Subsequent studies failed to yield a comparable proportion of positives, but 3 out of 30 later cultures on wound cases were also positive for Clostridia. There was no indication that this blood stream invasion was persistent, and it may have been benign. However, it had not been thought that blood stream involvement was so widespread in war wound cases.

In view of the unexpectedly high proportion of early wounds harboring Clostridia and the continuing problem of wound infections observed at the general hospital level, a further study of similar wounds was made under conditions permitting more extensive sampling and a closer liaison between the base laboratory and the MASH. These cultures were taken during December and January, 1952–53. Winter conditions altered the tactical situation: A higher proportion of patients were evacuated by ambulance because of decreased flying time available, so that the mean time from wounding to taking of cultures rose to 7.9 hours. Of the 87 patients who were studied, 43 showed Clostridia in débrided tissues. This striking drop in incidence of clostridial contamination could not be explained by any specific factor observed. It is possible that the fact that these patients' extremities were inevitably colder during the period between wounding and treatment may have retarded bacterial proliferation.

Of the 285 tissue samples cultured from patients who harbored Clostridia, 84, or 29 percent, were positive. This lowered proportion of positive tissues may well reflect the fact that more extensive sampling was done, so that samples of uncontaminated tissue were more frequently included. Among patients harboring Clostridia, an average of 2.9 species per patient were recovered, and among tissue samples "positive" for Clostridia, 1.5 species per sample were recovered.

Table 2 shows the predominant species recovered in the two series of observations. Seventeen species were recovered during the summer and 19 during the winter study. It will be seen that the predominant species in both studies was *Cl. sporogenes*, while the principal pathogenic species was *Cl. perfringens*. The incidence of *Cl. novyi* is noteworthy; 5 to 7 percent of the total strains recovered is less than one-third the incidence of this potent pathogen observed in other recent wars (*3*, *4*). The minor incidence of *Cl. septicum* in contrast to its

importance in World War II is also notable. Of the remaining species, only *Cl. sordelli* is generally regarded as pathogenic. (*Cl. tetani* will not be discussed here since it does not fall within the scope of this study.) *Multifermentans*, *lentoputrescens* and *paraputrificum* were the other species of principal interest.

Table 2. Clostridia Flora in Two Series of Recent War Wounds

Species	Summer 1952		Winter 1952–53	
	Number	Percent of total strains	Number	Percent of total strains
Sporogenes	40	29	25	20. 3
Perfringens	29	21. 2	22	17. 8
Bifermentans	15	11	3	2. 4
Sordelli	4	2. 8	4	3. 2
Multifermentans	11	8. 0	3	2. 4
Novyi	10	7. 2	7	5. 6
Paraputrificum	5	3. 6	7	5. 6
Tetanomorphum	4	2. 9	2	1. 6
Butyricum	3	2. 2	1	0. 8
Tertium	3	2. 2	3	2. 4
Lentoputrescens	3	2. 2	6	4. 8
Tetani	3	2. 2	4	3. 2
Carnis	1	0. 7	4	3. 2
Aerofoetidum	2	1. 4	2	1. 6
Histolyticum	1	0. 7	0	0
Cochlearium	1	0. 7	2	1. 6
Putrifaciens	1	0. 7	1	0. 8
Sphenoides	1	0. 7	2	1. 6
Difficile	0	0	1	0. 8
Capitovale	0	0	3	2. 4
Fallax	0	0	2	1. 6
Unclassified and unidentified	0	0	19	15. 3
	139		123	
		Percent of total		*Percent of total*
Number of *patients* with Clostridia	30	90	43	57
Number of *tissues* with Clostridia	63	67	84	29. 6

The flora of the environment, including the skin surface, clothing and soil of the combat area, was cultured during this investigation to obtain an indication of the actual source of wound contaminations. The skin surface harbored, among total strains recovered, 25 percent of *Cl. sporogenes* and 23 percent of *Cl. perfringens*, with small numbers of *bifermentans*, *novyi* and *paraputrificum*. A total of 17 species

were found. This pattern most closely resembled that seen in the fresh wound. Only 0.7 strain per skin swab was recovered, which proportion may reflect the difficulties of survival of Clostridia on swabs even in an optimal environment. Clothing and soil showed an essentially similar population, predominantly *Cl. perfringens* (32 percent to 37 percent), with 12 percent to 20 percent of *Cl. sporogenes*. This reversed ratio of predominant species between wounds and soil, with a closer correspondence between skin and wound flora, lends credence to an hypothesis that wound contamination in this type of warfare is primarily a seeding of tissues with skin flora, rather than that of soil or clothing. An additional observation bearing on this point is the low incidence of *Cl. buytyricum* in wounds at the MASH level, and its virtual absence in wounds cultured later. It appears that even when soil bacteria are driven into a wound, nonadapted species are promptly eliminated. Of exceptional interest is the fact that *Cl. tetani* was never recovered from Korean soil, although there was no difficulty in recovering it from tissues.

Wounds at Evacuation Hospital Level

At the evacuation hospital level data are less available because of the difficulties of followup of this extremely mobile population. However, on the basis of 145 cultures identified from wounds at the 11th Evacuation Hospital during early 1953, some conclusions may be drawn: The incidence of *Cl. sporogenes* and of *Cl. perfringens* strains remained approximately that noted at the MASH. *Cl. novyi*, relatively infrequent at the MASH level, here made up 13 percent of the strains recovered. *Cl. multifermentans* also increased in incidence from approximately 6 percent to 12 percent, while *Cl. bifermentans* decreased in incidence from approximately 10 percent to 4 percent. The total of 19 species of Clostridia recovered included most of those observed throughout the chain of evacuation, although one rare species, *Cl. histolyticum*, was found twice. Table 3 summarizes this information.

Wound Flora in General Hospitals

From Japan most cultures obtained were taken on patients who were not responding well to treatment. Delayed primary closure of a clean wound, within 6 days of wounding, was the rule, and such wounds, which might have shown extensive tissue contamination at the MASH, would not usually be cultured again prior to closure.

Table 4 shows the results for 1951 and 1952 in specimens submitted for culture from general hospitals. Seventy-four percent of the cases yielded Clostridia, and 67 percent of the tissues cultured were positive.

Table 3. Flora of Wounds at 11th Evacuation (2 to 4 days average since wounding), January through April 1953

Species	Strains	Percent of total	Species	Strains	Percent of total
Sporogenes	39	26. 8	Paraputrificum	4	2. 7
Perfringens	22	15. 1	Parabotulinum	3	2. 0
Multifermentans	17	11. 7	Tetanomorphum	1	0. 7
Bifermentans	6	4. 1	Aerofoetidum	4	2. 7
Novyi	19	13. 1	Butyricum	4	2. 7
Tetani	4	2. 7	Sphenoides	1	0. 7
Sordelli	1	0. 7	Tertium	2	1. 4
Carnis	5	3. 4	Cochleanium	1	0. 7
Histolyticum	2	1. 4	Unidentified	3	2. 0
Lentoputrescens	5	3. 4			
Capitovale	2	1. 4		145	

The predominant species was *Cl. perfringens*, which appeared more frequently than it did earlier in the course of wound treatment. *Cl. sporogenes* was the remaining dominant species. *Cl. lentoputrescens*, a proteolytic nonpathogenic species, was more common than has been observed in other series, while *Cl. novyi* was seen in only 4.6 percent of the total. This important pathogen showed a higher incidence in previous wars. The 23 species identified indicate the diversity of flora present. The unusual observation of *Cl. feseri* was made; this pathogen has apparently not previously been observed in human wounds. Another unique species was *Cl. difficile*, not previously reported in human cases (*6*).

Table 4. Clostridial Flora of Wounds at General Hospitals in Japan, 1951–52

Species	Strains	Percent of total	Species	Strains	Percent of total
Perfringens	127	36. 3	Difficile	1	0. 4
Sporogenes	76	21. 7	Filiforme	2	0. 8
Multifermentans	17	4. 8	Innominatum	2	0. 8
Bifermentans	18	7. 3	Capitovale	1	0. 4
Sordelli	1	0. 4	Histolyticum	4	1. 6
Lentoputrescens	29	12. 3	Carnis	2	0. 8
Novyi	11	4. 6	Sphenoides	2	0. 8
Cochlearium	7	2. 9	Septicum	4	1. 6
Tertium	6	2. 7	Butyricum	2	0. 8
Chauvoei (feseri)	3	1. 1	Aerofoetidum	2	0. 8
Tetani	7	2. 9	Unclassified	13	3. 7
Paraputrificum	8	2. 9			
Tetanomorphum	4	1. 6		349	

Bacterial Flora of Amputations

In a series of 41 cases in which amputation was performed at a general hospital, tissue blocks from the amputated specimen were removed and cultured. The results of clostridial cultures are summarized in table 5. In these cases the predominant organism was again *Cl. sporogenes*, with *Cl. perfringens* observed half as often. This represents a reversal of the ratio of these species noted at the general hospital level. Three other species, *multifermentans*, *bifermentans* and *novyi*, were more common than they were in the hospital cases. *Cl. feseri*, which has been regarded as only a pathogen of horses, was recovered here as it was at the general hospital level.

Table 5. Clostridial Flora of 109 Amputation Specimens from 41 Cases of Clinical Gangrene due to Wounds, 1952

Organism	Number of strains	Percent of total strains	Number of patients	Percent of total patients
Perfringens	18	16. 5	13	31
Sporogenes	38	34. 8	23	56
Multifermentans	14	12. 8	10	24
Bifermentans	10	9. 0	8	19
Novyi	9	8. 0	9	21
Lentoputrescens	4	3. 6	4	9. 7
Cochlearium	3	2. 7	3	7. 3
Histolyticum	2	1. 8	1	2. 5
Carnis	2	1. 8	2	5
aerofoetidum	2	1. 8	2	5
Sordelli	2	1. 8	2	5
Chauvoei (feseri)	1	0. 9	1	2. 5
Tetani	1	0. 9	1	2. 5
Pasteurianum	1	0. 9	1	2. 5
Tertium	1	0. 9	1	2. 5
Tetanomorphum	1	0. 9	1	2. 5
Total	109			

Average number of Clostridia per patient=2.7.

Assay of tissues of 28 patients at amputation was performed for determination of penicillin level in the muscle and other tissues. Proximal, viable samples of muscle showed an average of 0.26 unit of penicillin per gram, while the more distal samples contained on an average of 0.22 unit per gram of muscle. These levels are about one-fourth of the corresponding blood content of penicillin in these cases. No specific correlation of antibiotic content and of clostridial flora was observed in the tissues assayed.

WEDNESDAY AFTERNOON SESSION

Aerobic Wound Flora

The aerobic flora of wounds at the various intervals described was determined in random samples of tissues. Streptococci and Staphylococci comprised over 50 percent of the total flora at the MASH, with *Bacillus* strains numbering 15 percent of the total. Coliform bacilli were prominent. The remainder were chiefly *Pseudomonas* and *Proteus* forms. At the evacuation hospital, a marked rise in the proportion of *Proteus* and *Pseudomonas* occurred. When patients reached the general hospital, an increase in the proportiton of Staphylococci appeared and coliform incidence fell. Streptococci were chiefly *alpha* and non-hemolytic forms, with hemolytic Streptococci occurring more frequently later in the healing process. The vast preponderance of hemolytic Streptococci were group D. Group A Streptococci were particularly infrequent in early wounds.

Sensitivity of Wound Flora to Antibiotics

Sensitivity of wound bacteria to antibiotics was determined on a total of 520 strains of recently isolated Clostridia. Extreme care in maintaining the proportion of inoculum to antibiotic dilution was found to be essential in order to obtain consistent results in sensitivity determinations with this group.

Table 6 illustrates the sensitivity of the principal species of clostridial flora of wounds. Approximately 85 percent of strains were sensitive to penicillin, aureomycin and terramycin; chloromycetin was relatively less effective on most strains. A small but significant proportion of strains were relatively resistant. This suggests that antibiotic resistance may well appear with sufficient readiness to constitute a problem in this situation.

When results of antibiotic sensitivity in successive years were studied, it was found that the proportion of Clostridia strains sensitive to penicillin fell from 94 percent in 1952 to 84 percent in 1953. The percentage sensitive to aureomycin and to terramycin remained constant or rose slightly during this time. Among other antibiotics tested, 100 percent of the strains were inhibited by 20 units of bacitracin.

Penicillin-resistant strains included *bifermentans*, *novyi* and *sporogenes*, among others.

Aureomycin- and terramycin-resistant strains occurred among *perfringens*, *capitovale*, *lentoputrescens* and *sporogenes*. *Carnis* was particularly resistant to terramycin. No specific relationship between age of wound and resistant strains was noted. In tests on the aerobic flora, the pyogenic cocci tended to be more often resistant to penicillin at all levels. Aureomycin and terramycin were most often effective

against the Staphylococci. The hemolytic group D Streptococci were predominantly resistant to all antibiotics tested. *Proteus* and *Pseudomonas* were largely resistant to all antibiotics tested, while Coliforms were most effectively inhibited by aureomycin and terramycin.

Table 6. Range of Concentration of Antibiotics which Inhibit More than 80 percent of Clostridium perfringens, multifermentans, bifermentans, sporogenes and novyi

Antibiotic	Clostridium species: Perfringens	Multifermentans	Bifermentans	Sporogenes	Novyi
Terramycin					
Minimum units inhib. conc.	0. 1–1. 0	0. 05–0. 5	0. 05–0. 5	0. 1–1. 0	0. 25–1. 0
Number of strains tested	193	45	60	135	7
Percent of total inhibited	88. 7	88. 8	91. 7	89. 6	85. 7
Aureomycin					
Minimum units inhib. conc.	0. 05–0. 5	0. 05–0. 5	0. 05–1. 0	0. 1–1. 0	0. 1–1. 0
Number of strains tested	189	47	65	132	9
Percent of total inhibited	92. 8	89. 4	90. 8	91. 0	88. 8
Penicillin					
Minimum units inhib. conc.	0. 1–1. 0	0. 05–1. 0	0. 05–1. 0	0. 1–2. 0	0. 05–1. 0
Number of strains tested	184	36	57	132	9
Percent of total inhibited	89	86. 4	94. 7	91. 7	88. 8
Chloromycetin					
Minimum units inhib. conc.	2. 5–10. 0	2. 5–8. 0	2. 5–8. 0	2. 5–10. 0	2. 5–10. 0
Number of strains tested	186	43	63	126	8
Percent of total inhibited	81. 5	83. 7	85. 2	90. 0	75. 0

inhib.=inhibiting.
conc.=concentration.

Summary

A series of observations on war wounds from the MASH level to the general hospital showed a significantly high degree of contamination of tissues with a mixed clostridial and aerobic population. The initially predominant species was *Cl. sporogenes*, followed by *Cl. perfringens*. However, as the patients moved down the chain of evacuation, those wounds still contaminated to an extent which occasioned culture exhibited a higher and higher proportion of *Cl. perfringens*, with *Cl. sporogenes* second in significance. *Cl. novyi* was conspicuously lower in incidence than has been noted in previous wars, and *Cl. septicum* was virtually a rarity, in contrast to findings in Europe and North Africa. In specimens from amputations, the Clostridia once more showed a lowered incidence of *Cl. perfringens*, with a predominance of *Cl. sporogenes* and numerous proteolytic forms present. From 19 to 27 species were collected at the various levels

of study. The aerobic flora comprised primarily pyogenic cocci, gram-positive bacilli and coliform bacteria. Group A Streptococci were not encountered. The major part of the aerobic flora was penicillin-resistant, while penicillin, aureomycin and terramycin were inhibitory to the major portion of the clostridial strains.

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THE EFFECT OF SEVERE BATTLE INJURY AND OF POST-TRAUMATIC RENAL FAILURE ON RESISTANCE TO INFECTION*

MAJOR HENRY H. BALCH, Jr., MC, USAR

Introduction

Acute infection remains one of the serious complications of severely wounded soldiers. Its incidence, in terms of total casualties in Korea, was probably low; possibly 20 percent of the severely wounded who were resuscitated had complicating infection. About 5 percent of severely injured develop acute renal failure, and the incidence of infection is high in this group also. There are several reasons why severely wounded casualties may be more prone to infection—these include such things as the degree of tissue damage, the amount of bacterial contamination, delay in initial and subsequent surgical treatment, errors in judgment, etc.

The purpose of today's presentation is to discuss the possibility that severely wounded casualties and those with acute renal failure may be more prone to infection because of some breakdown in basic body defense.

There are several natural mechanisms of body defense following bacterial penetration. The microorganisms may be trapped or eliminated by lymph nodes draining the area. Cells of the reticuloendothelial system or wandering phagocytes may ingest and destroy pathogens. This process is much more effective if specific antibody is present. In addition, natural and specific antibody (globulin) participates in the lysis of a number of bacterial species and also neutralizes the products of others. A group of proteins found in normal serum which have been called complement possess several properties of importance in antibacterial defense; these include a capacity to kill bacteria sensitized by antibody and to render the microorganisms more susceptible to phagocytosis. If a defect in globulin synthesis or a depression of reticuloendothelial cell function or leukocyte activity follows severe injury, the defense effort might be impeded seriously and such patients become prone to infection.

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In this investigation I attempted to measure the phagocytic activity of circulating leukocytes, the serum complement levels and the capacity of a patient to synthesize specific antibody, and then I tried to correlate the findings with the clinical course and with the presence or absence of infection. The methods were simple. For phagocytosis we took fresh specimens of blood and counted the number of neutrophils; we mixed a known number of neutrophils with a known number of pathogenic Staphylococci, rotated these in a 37° C. incubator, and at a fixed interval we counted the number of neutrophils which had ingested organisms, and so estimated their activity. Complement was assayed by measuring the least amount of plasma which would hemolyze specifically sensitized sheep red cells. The capacity to synthesize antibody was determined by measuring the response to the booster injection of tetanus toxoid immediately following wounding. The series was small because only severely wounded patients were studied.

Phagocytosis

Table 1 shows the number of neutrophils which ingested Staphylococci in 2 groups of patients, 6 nonwounded and 12 lightly wounded; 94 percent of the neutrophils from nonwounded and 88 percent from the lightly wounded showed staphylococcal ingestion. These differences could have been due to chance; therefore, neutrophils from the lightly wounded group appear to have been just as active as were those from individuals not exposed to combat conditions.

Table 1. Phagocytosis Related to Injury

	Postwound day	Number of subjects	Percent neutrophils showing ingestion	Standard error of means
Nonwounded	0–1	6	94. 4	±2. 18
Lightly wounded	0–1	12	88. 2	±2. 5

Table 2 records phagocytosis from two groups of severely wounded patients; those without oliguria and those with oliguria. The only real abnormality in this table is the figure 68.4 percent in the group of patients without oliguria, who were studied within the first 24 hours of wounding. That group showed a significant depression in the ability of neutrophils to ingest Staphylococci. But, as the days went by, the neutrophils appeared normally active again. Neutrophils from patients with post-traumatic renal insufficiency appeared to possess normal activity.

Table 2. Phagocytosis Related to Injury

Post-wound day	Number of subjects	Percent neutrophils showing ingestion	Standard error of means
Severely Wounded without Clinical Post-traumatic Renal Insufficiency			
0–1	6	68. 4	±5. 5
1–2	5	61. 2	±12. 1
2–3	4	81	±4. 2
3–4	5	82	±5. 4
Severely Wounded with Post-traumatic Renal Insufficiency			
1–2	5	83. 6	±3. 7
2–3	8	82	±1. 7
3–4	6	83	±2. 1

Table 3 shows some data of interest in connection with white cell counts, and neutrophil activity immediately following the administration of very large transfusions. There were eight patients, the volumes of blood used in resuscitation ranged from 5 to 26 liters, and a few of them had a liter or so of dextran also. It is of interest that the white blood counts were high although the bank blood contained very few white blood cells, especially neutrophils. There was an

Table 3. Leukocyte Count and Mean Ingestion of Staphylococci by Neutrophils Immediately Following Large Blood Transfusions

Patient number	Post-wound day	Volume blood used in resuscitation	Volume dextran used in resuscitation	WBC per cu. mm.	Percent neutrophils	Percent neutrophils containing Staphylococci
		L	*L*			
3	1–2	5	1. 9	15, 400	73	56
4	1–2	5	----------	14, 000	81	18
15	0–1	7	0. 5	13, 250	72	66
16	0–1	7. 5	----------	14, 650	70	56
21	0–1	8. 5	1. 0	16, 800	79	62
26	0–1	*5. 5	1. 0	15, 800	76	56
	0–1	10	----------	13, 400	66	62
	0–1	12	----------	16, 600	72	74
	0–1	13	----------	15, 300	74	70
27	0–1	*12	----------	9, 850	80	88
	0–1	23	----------	11, 850	77	90
28	0–1	26	----------	5, 500	70	82

*Volumes of blood are reported on a cumulative basis.

elevation in the percentage of neutrophils in the blood from these patients; but as I have already pointed out, on this first post-wound day, in this severely wounded group, there was a depression in the activity of these neutrophils. In two of these patients we found no significant drop in neutrophil activity. I have no explanation for the observed depression in neutrophil activity in the other patients. The subsequent recovery in phagocytic activity within 2 or 3 days of injury may have been the result of the outpouring of new neutrophils from the bone marrow. It is of interest that two of the patients who received the largest volumes of blood showed no depression of neutrophil activity, which suggests that the depression was not due to factors added by the bank blood, such as citrate. I do not have any data on neutrophil activity before resuscitation was commenced so I do not have any information on neutrophil activity immediately after severe injury.

The observed depression in neutrophil activity might possibly have been a manifestation of adrenal cortical hyperactivity. Others have reported finding a depression in the phagocytosis of opsonized pneumococci in a few patients under ACTH or cortisone therapy, but we did not find any fall in staphylococcal ingestion in a few nonwounded patients on ACTH therapy. Others too, in animals, have not found any depression of either reticoloendothelial cell function in rats treated with cortisone or of macrophage activity in tissue culture exposed to Kendall's compounds E or A. So, this depression in neutrophil activity in the first few hours after injury remains an interesting observation as yet unexplained.

Figure 1 shows the mean percentage neutrophil activity in two groups of patients. On the left are patients without oliguria and on the right those with oliguria. The differences in the groups could have been due to chance. Neutrophil activity in the blood of two individuals in the nonoliguric group showed a depression. The barred lines represent patients who died of uncontrolled infection. The other patients either had infection which was controlled or did not have significant infection. A number of these died, as you can see. We were not able to find any particular difference between neutrophil activity over the entire course of illness in the two groups.

Complement

Table 4 records complement activity from the blood of lightly wounded and seriously wounded patients without oliguria. These are recorded as the dilutions of plasma required to hemolyze a standard volume of sensitized red cells. The values for the lightly wounded are probably normal. Complement titers in seriously wounded patients without oliguria were not significantly different.

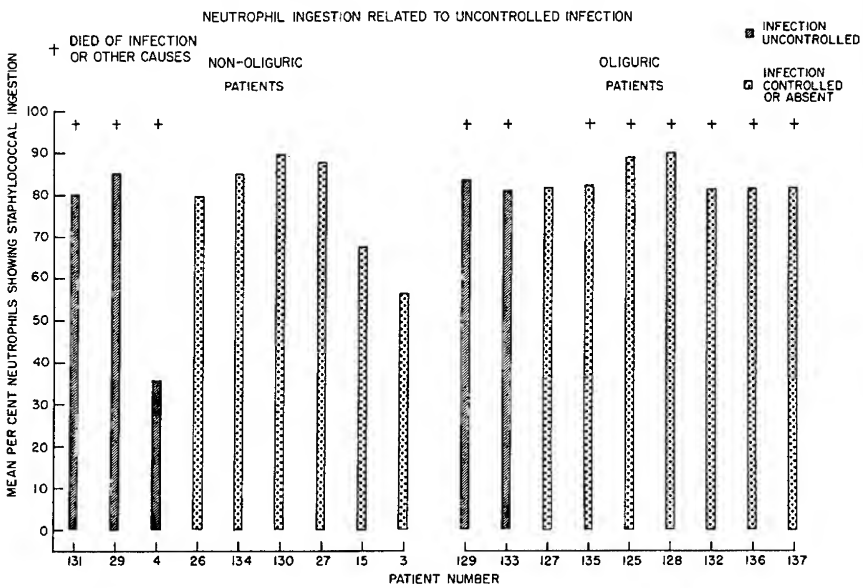


FIGURE 1.

Table 4. Complement Activity in Plasma of Battle Casualties
End Point=100 Percent Hemolysis

Lightly wounded	Seriously wounded without oliguria
17 patients	14 patients

Post-wound day

Titer (reciprocal)	0–1 number of patients	Number of patients 0	1	2	3	4	5
64	--	--	--	--	1	--	--
32	12	1	2	--	2	1	1
16	5	5	4	--	2	1	--
8	--	1	2	3	1	--	1
4	--	1	--	--	--	--	--

Table 5 shows complement titers in 12 patients with post-traumatic renal insufficiency. And again, the levels of complement on the various post-wound days were not significantly different from those found in the control series. We had four isolated samples from different patients which showed no complement activity, but they did not follow any consistent pattern. Complement may vary in different dis-

Table 5. Complement Activity in Plasma of Battle Casualties End Point=100 Percent Hemolysis

Seriously wounded with Oliguria, 12 patients, post-wound day

Titer (reciprocal)	Number of Patients						
	1	2	3	4	5	6	7
32	--------	1	1	1	2	1	--------
16	1	1	3	3	--------	1	--------
8	1	1	1	--------	2	--------	1
4	--------	--------	--------	--------	--------	--------	--------
<1	2	--------	--------	--------	--------	--------	2

eases in an unpredictable fashion. If these zero levels had been consistently present over several days, I would have considered them of importance, but the finding of apparently normal complement activity on the preceding and following days makes me hesitate to interpret this as a significant observation.

The finding of probable normal complement activity in most cases following acute hemorrhage or trauma under the conditions of this study agrees with observations of others, on the effect of hemorrhage on complement levels in animals. The removal of 50 to 83 percent of circulating complement from dogs by repeated plasmaphoresis has been reported to be followed by a return of normal serum titer within 24 hours. In guinea pigs restoration of complement occurred within 4 to 6 hours after removal by severe hemorrhage. It is probable that complement continually enters the intravascular compartment by diffusion from tissues or by the lymphatics.

Antibody

Figure 2 records antibody synthesis in two patients without renal failure. This type of study is difficult in severely wounded patients because of the need for repeated observations, so the series was small. The figure shows the antibody response of two patients with severe injury. The response of two normal controls is also recorded. The secondary immune response to a specific antigen in normal adults may not appear for 6 days or perhaps longer; therefore, the response observed in the 2 nonoliguric casualties studied cannot be said to be abnormal. One patient had not responded by the seventh day, but he had been in severe shock so there may have been either a loss or a delay in the absorption of antigen, and so a delay in the subsequent synthesis of antitoxin.

Figure 3 shows the antitoxin response of five patients with post-traumatic renal insufficiency. It is quite clear from this figure that

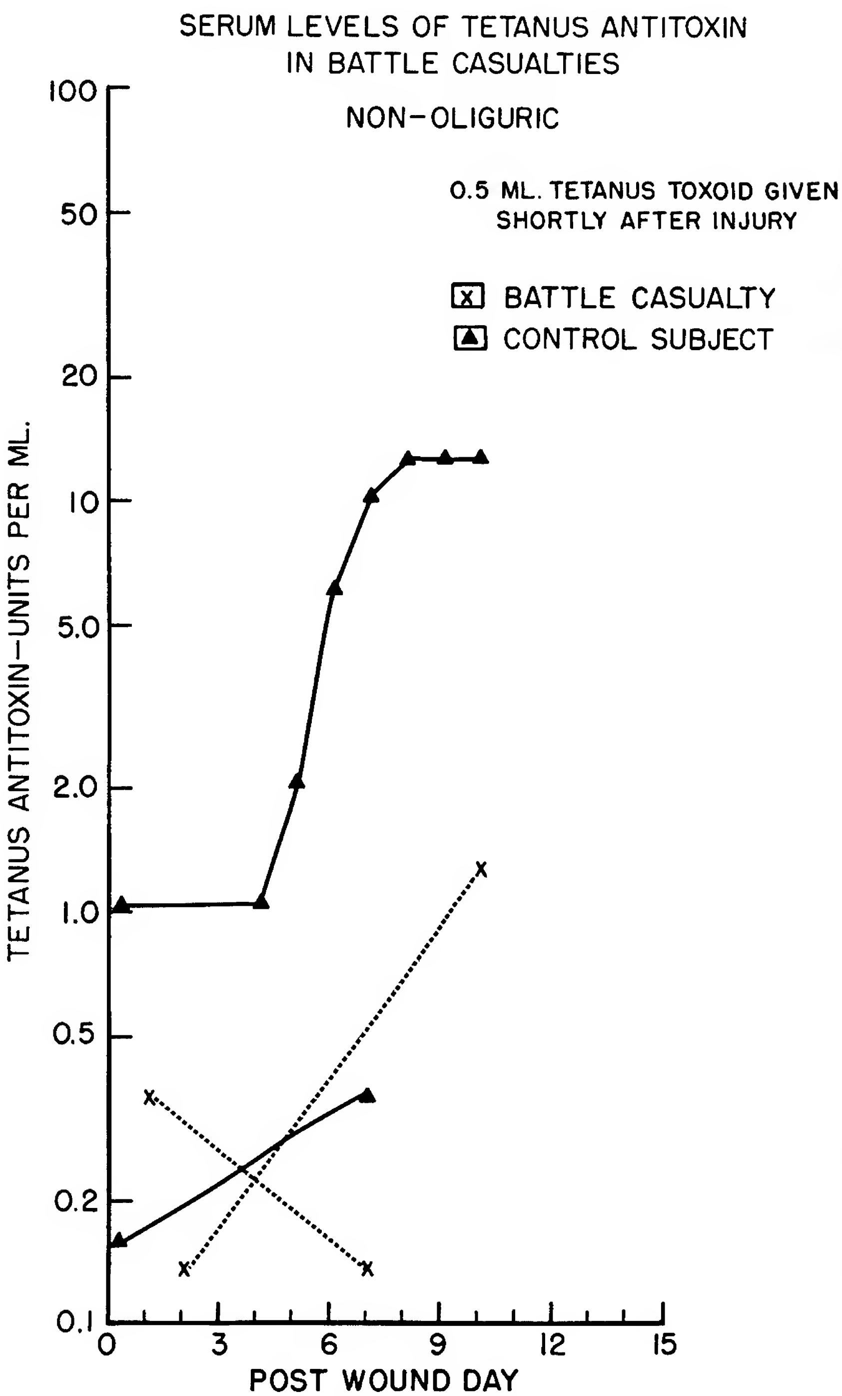

SERUM LEVELS OF TETANUS ANTITOXIN
IN BATTLE CASUALTIES
NON-OLIGURIC
0.5 ML. TETANUS TOXOID GIVEN
SHORTLY AFTER INJURY
BATTLE CASUALTY
CONTROL SUBJECT
TETANUS ANTITOXIN-UNITS PER ML.
100
50
20
10
5.0
2.0
1.0
0.5
0.2
0.1
0
3
6
9
12
15
POST WOUND DAY

FIGURE 2.

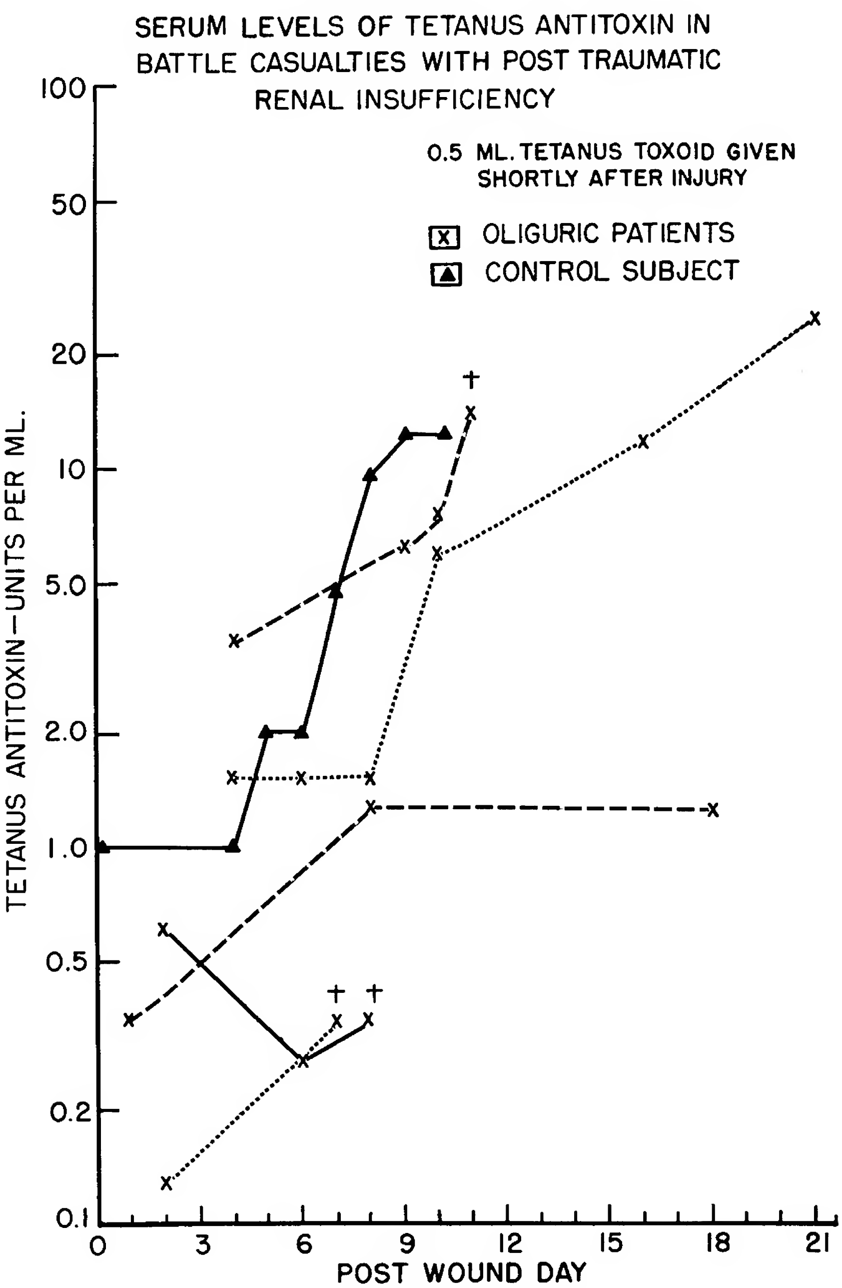


FIGURE 3.

patients with acute renal failure may synthesize antibody in a comparable manner to control subjects. One of these patients failed to produce any detectable antitoxin until the sixth day when it began to rise,

at which point the patient died. Again, it cannot be said that this was abnormal.

The finding of normal antibody synthesis in severely wounded casualties is not surprising. In previous observations we showed that moribund patients retained the capacity to synthesize specific antibody as well as or better than healthy subjects. Furthermore, observations on guinea pigs have shown that a response to antigenic stimulation occurred after protracted exposure to cold, after the production of severe clostridial myositis, and after attempts to block the reticuloendothelial system with large amounts of India ink. The absence of a detectable increase in circulating antitoxin until about the sixth or seventh post-wound day in three of the patients is of interest. There has been considerable discussion about the desirability of administering prophylactic tetanus antitoxin to previously immunized casualties instead of toxoid at the time of injury. This was the practice of the British Army in World War II because of the possibility that the response to the booster dose of tetanus toxoid might not be sufficiently rapid to protect in cases of tetanus with a short incubation period. Miller and Ryan have recently advised the injection in opposite extremities of prophylactic antitoxin and toxoid to previously immunized patients who have sustained shock or who have massively contaminated wounds. The data in this study lend some support to that proposal which might be particularly important if the level of circulating antitoxin in a patient happened to be low.

I would like now to present briefly two cases, one without post-traumatic renal insufficiency and the other with it.

First, a Marine who sustained a land mine injury resulting in a bilateral traumatic amputation of the lower extremities and a compound fracture of the right humerus. His wounds were débrided initially but at the evacuation hospital a re-amputation was required because of myositis in the stumps. His subsequent course was reasonably satisfactory and he was evacuated to Japan and the wounds have since undergone successful secondary closure. Figure 4 shows some of the clinical data. The daily white counts and phagocytic activity showed no depression. Daily complement levels, except for one, were within the normal range, and tetanus antitoxin rose from 0.35 unit per ml. to 1.23 units per ml. This patient represents an injured casualty who had extensive initial surgery, but developed myositis in the amputation stumps which was controlled by surgery. He did not have any apparent defect in antibacterial defense.

The other was a patient who had sustained a mortar injury of the left buttock penetrating through to the pelvis. On examination at the evacuation hospital it was obvious that the wound had been inadequately débrided. The incision was small, large areas of muscle

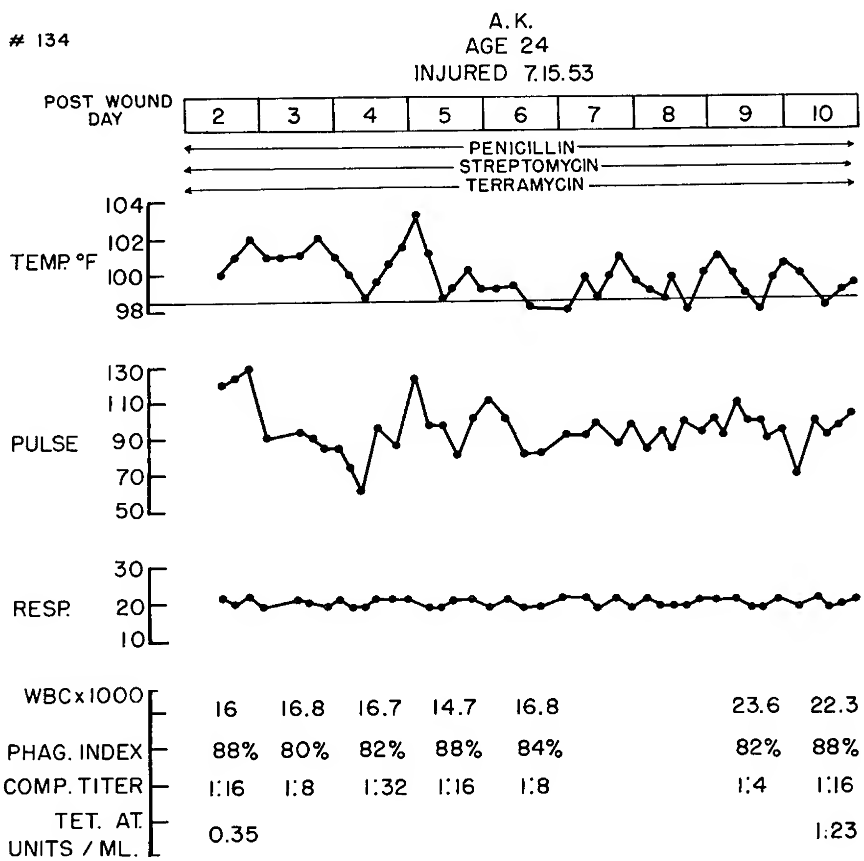
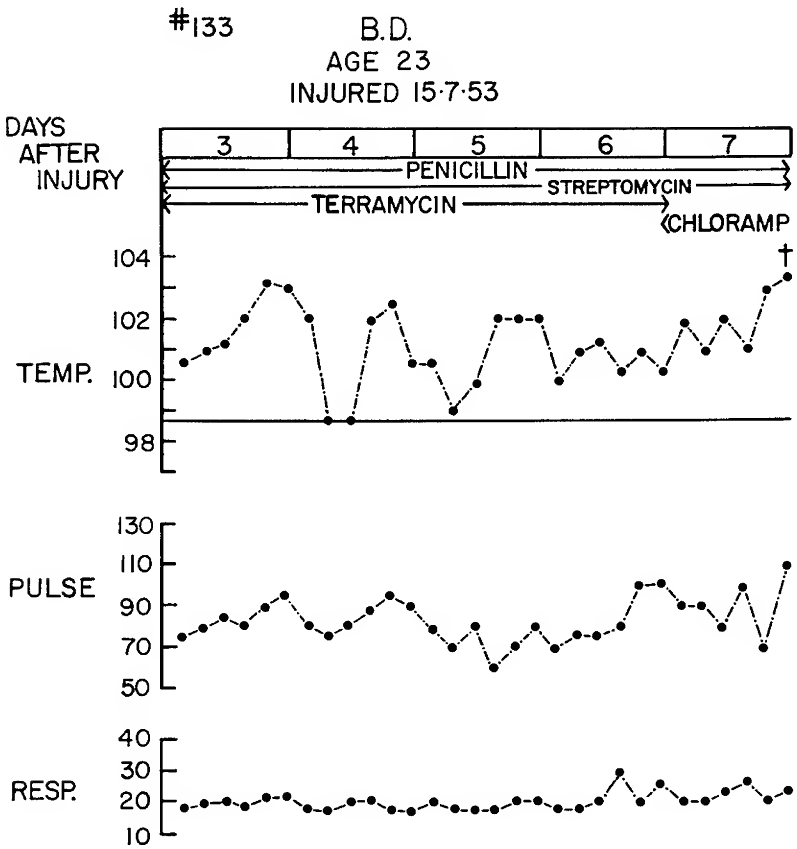


FIGURE 4.

were not viable and, moreover, the patient's I. D. card was in the wound. An extensive débridement of the buttock muscle was done. He had a clostridial-like myositis of his left lower leg which required a supracondylar amputation. In addition, he had renal insufficiency. He developed a septicemia which we think was the final cause of death. We found no focus of infection at autopsy other than the surface infection of the buttock. The following figure (fig. 5) presents data on the chemotherapy used in an attempt to control the paracolon septicemia. White blood cell counts were elevated, and phagocytosis and complement levels were relatively normal. There was a rise in tetanus antitoxin from 0.13 unit per ml. to 0.35 unit per ml. The data on ati-bacterial defense from this patient look quite similar to those from the previous patient. Yet, he developed septicemia and the other did not. One had a myositis in an extremity which we were able to re-amputate completely and so obtain a cure. The other had



W.B.C. X 1000	16.2	16.6	15.4	17.1	19.1	18.8
PHAG. INDEX	86%	78%	78%	80%	78%	78%
COMP. TITER	1:16	1:8	1:16	1:32	1:16	1.8
TET. AT. UNITS/ML.	0.13					0.35
BLOOD CULTURE	NEG.	NEG.	POS.	POS.	POS.	

FIGURE 5.

extensive pelvic injury which we were not able to débride to our satisfaction.

In conclusion, then, I found that neutrophils from a few severely wounded patients show decreased activity. In addition, there may be a delay in the appearance of tetanus antitoxin following the administration of a booster dose of toxoid to such patients. Apart from that, I found no evidence that severely injured casualties with or without post-traumatic renal insufficiency were more susceptible to infection because of some breakdown in antibacterial defense mechanisms. On

the other hand, the other evidence I have gathered suggests that the combination of extensive trauma with bacterial contamination plus less than optimal surgical therapy will explain why infectiton developed in many of the cases.

THE OCCURRENCE OF INFECTION IN KOREAN WAR BATTLE CASUALTIES DURING MAY–JUNE 1953 (REPORT ON KOREAN TOUR)*

William A. Altemeier, M. D., and Lieutenant Colonel Edwin J. Pulaski, MC

1. *Purpose of Mission.* Dr. William A. Altemeier, Consultant to The Surgeon General and Professor of Surgery of the University of Cincinnati, and Lieutenant Colonel Edwin J. Pulaski, Army Medical Service Graduate School of Washington, D. C., were commissioned to review surgical activities in this theater during May and June 1953, concerned with the following:

a. A study of the incidence, nature, and severity of infections complicating war wounds and their effect on secondary shock and wound healing.

b. A study of incidence of contamination and infection by Clostridia in war wounds.

c. An appraisal of the influence of antibiotic treatment in the prophylaxis and control of infections.

d. Collection of data on which to base the need for the potential usefulness of clostridial toxoid immunization for prophylaxis.

2. *Activities.* The following medical installations were visited:

a. 406th Medical General Laboratory. Conferences, examinations, and review of data pertaining to bacterial contamination and infection of war wounds including the physiological and pathological changes in wounded personnel.

b. Tokyo Army Hospital. Examination and discussion of wounded patients on Ward Rounds, Lectures to Staff.

c. 46th, 43rd, and Norway Mobile Army Surgical Hospitals; 11th and 121st Evacuation Hospitals; U. S. N. Hospital Ship Haven; Severance Medical School and Hospital; Meeting of 38th Parallel Medical Society. Activities at these installations followed much the same pattern, including careful examination and study of all wounded patients; observation of, and participation in, surgical operations; teaching ward rounds and lectures; conferences with members of the Surgical

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Research Team and surgeons of the various hospitals; dressings, photographs, and spot bacteriological checks on the bacterial flora of many of the infected wounds.

3. *Acknowledgment.* We received the greatest cooperation at all levels, both in Tokyo and Korea, for the successful accomplishment of our mission. Information was readily given, access to all wounds and wounded patients was granted, and the desire for suggestions and recommendations was expressed voluntarily. In effect, the cooperation given us was exemplary. The accomplishment of the mission was greatly expedited by the efforts of Brigadier General L. Holmes Ginn and Colonel J. K. Davis, MC, who accompanied us on our tour, and Major General William E. Shambora and Colonel R. P. Mason, MC, who directed it from Tokyo. We were impressed with the efficiency and morale of the surgical officers in the forward areas, particularly in the Mobile Army Surgical Hospitals. The eagerness of the men to work and learn was apparent everywhere. The shortness of the time between injury and definitive care at the MASH level was most gratifying.

The outstanding value of the Surgical Research Team and the Renal Insufficiency Team was readily apparent, not only through the data accumulated but more directly by their effect on the surgical practice in that area.

The system of triage and evacuation was efficient and effective. Standardized operative procedures had been well taught to the medical officers, and the wisdom of their conception was obvious.

4. *Observations.* The data on which this report is based include the information collected at the 406th Medical General Laboratory in Tokyo, information gathered from medical officers at all levels, and personal observations on approximately 650 patients with wounds seen at the Mobile Army Surgical Hospital, Evacuation Hospital, and Tokyo Hospital levels. It was possible to see this many casualties because ground action during this period was moderately intense and continuous.

a. Distribution and Types of Wounds. The wounds observed by us were representative samples of the overall distribution of body hits collected by Holmes in the Korean conflict. Holmes' data indicated distribution of wounds as follows:

	Percent
Head	16
Thorax	8
Abdomen	6
Upper extremities	26
Lower extremities	44

Head and thoracic wounds accounted for over 50 percent of those killed in action or dying subsequently. Thoraco-abdominal and ab-

dominal wounds were next in order as a cause of death. The fewest deaths resulted from injuries of the extremities.

Contrary to our expectations, the general distribution of wounds observed by us had not been appreciably altered by the previously introduced armored vest. The decrease in abdominal and thoracic wounds in American personnel, brought about by the introduction and wearing of the armored vest, apparently was compensated for by the numbers of such casualties among the ROK troops who did not have the armored vest and who were in the lines in greater numbers than in the earlier part of the war.

The general pattern of injury observed by us was that of multiplicity of wounds, some of which were confined to the same area while others involved other general areas of the body. It is worthy of note that Holmes' figures indicated a regional wound incidence per casualty of approximately two.

The incidence of penetrating wounds was greater than that of perforating wounds, the ratio for the various regions being similar to those cited by Holmes:

Head	17:1
Thorax	8:1
Abdomen	5:1
Extremities	3:1

Wounds of all degrees of severity were observed in this group, including simple wounds without shock to the most complex wounds with severe shock culminating in death.

b. Causal Agents. In our tour the majority of wounds observed were produced by fragmentation missiles. Mortar shell, high-explosive shell, or hand grenade projectiles produced the majority of injuries; rifle or machinegun fire produced the minority. Land mine wounds were seen infrequently, only three being noted in the entire group of approximately 650.

The incidence of the causal agents producing wounds is shown in the following table based upon personal observations made during surgical rounds at the 11th Evacuation Hospital on 5 and 6 June 1953. Ninety-three patients having a total of 128 wounds were examined. Thirty-four of the patients were United States Army personnel, 58 were ROK soldiers, and 1 was a prisoner of war. The causes of the wounds were as follows:

Mortar fire	48
Artillery shell	11
Rifle	21
Hand grenade	11
Machine gun	1
Land mine	1

These figures were similar to those reported in certain periods of World War II, and closely parallel those of Holmes for the Korean campaign:

	Percent
Mortar wounds	37
Bomb and grenade wounds	21
Gunshot wounds	17
Shell and high-explosive wounds	12
Land mines	6
Battle accidents	6
Burns	1

Many of the mortar wounds seen by us were relatively superficial and extended to the subcutaneous tissues and the fascia only with relatively little involvement of the underlying muscle.

c. Contamination of Wounds. Bacteriological studies of battle wounds have revealed that all war wounds were contaminated at the time of the first examination following injury (primary contamination). In reviewing the data of Colonel Lindberg on 234 Korean war wounds, it was found that all were contaminated with more than one species of bacteria.

Three principal classes of bacteria were found: the anaerobic spore-forming bacilli, micrococci, and gram-negative bacilli. Over 67 percent of the wounds were contaminated by one or more strains of Clostridia. An average of four species per patient and of two strains per tissue sample were recovered. The five pieces of imbedded clothing yielded 1.8 strains per sample, with 9 strains and 5 species being represented. The incidence of clostridial contamination was greatest in wounds caused by artillery fire (88 percent), less in those caused by mortar fire (65 percent), and least in those caused by small arms fire (55 percent). The average number of species of Clostridia per patient varied from 1.3 in the case of small arms fire to 6.0 in land mine wounds. The studies of the anaerobic flora yielded 19 species of Clostridia. Predominant among these were *Cl. sporogenes*, *Cl. perfringens*, *Cl. bifermentans*, *Cl. multifermentans*, and *Cl. novyi*. Toxigenic species (excluding *Cl. tetani*) included *Cl. perfringens*, *Cl. novyi* and *Cl. sordelli*. Pyogenic micrococcal contamination of wounds consisted primarily of Streptococci and Staphylococci. During the early phases of the wound, primary seeding with the beta hemolytic Streptococci (group A) was uncommon, the hemolytic Streptococci that were found usually being of enteric origin and variety. The hemolytic Staphylococci were present in over 50 percent of the wounds.

Gram-negative bacilli appeared initially in 15 percent of the wounds. *B. proteus* and *Ps. aeruginosa* were found infrequently during the periods of contamination immediately after wounding, coliform bacteria being found relatively more frequently.

Serial studies showed that the bacterial flora of open wounds was rarely static, but usually changing or dynamic. Moreover, in patients with multiple wounds, variation of the bacterial flora from one wound to another was not uncommon.

Secondary contamination consisted of later inoculation of the wound by organisms from other sources. The bacteria most commonly participating in secondary contamination were the hemolytic Staphylococci, beta hemolytic Streptococci of human origin, and the gram-negative bacillary forms of *B. proteus* and *Ps. aeruginosa.*

Another interesting observation was that derived from culturing the skin of soldiers, both Korean and American. The cultures were done primarily for Clostridia. Contrary to expectations, the skin of Koreans showed less Clostridia than the skin of the United States soldiers, and the South Koreans did not have the marked bacterial flora which the Americans had. Their skin was free of Clostridia in most instances, and Clostridia were recovered in only 30 percent of the cases. This was difficult to understand after seeing the lack of cleanliness of the ROK soldiers. It conceivably may have been the result of the increased amount of hair that the American boys had on their skin in contrast to the exceedingly small amount which the Koreans had.

The presence and profusion of bacterial species in war wounds was remarkable in the face of the fact that each soldier had received, 1 to 4 hours previously, 600,000 units of procaine penicillin intramuscularly and 0.5 gram of streptomycin.

Inasmuch as surgical débridement represents physical cleansing of the wound, this form of therapy is not germicidal and bacteria remain as contaminants in the débrided wound. It is important to note, however, that the number and types of bacteria recovered 4 to 6 days after initial surgery were fewer in those wounds adequately débrided than in those inadequately débrided.

In a group of wounds closed 6 to 9 days after initial surgery, bacteria were recovered from the surface in every instance. The number of strains varied from one to eight. Forty-five percent showed the presence of beta hemolytic Streptococci resulting from secondary contamination. In the same way, 20 percent of the cases showed *Ps. aeruginosa* at this time and until healing. It was particularly noteworthy that the clostridial forms were found only in those wounds inadequately débrided in which variable amounts of necrotic tissue were still visible.

d. Nature and Severity of Infection. Our investigations indicated that infection continues to be an important complication of war wounds. Antibiotic therapy has not eliminated this complication, contrary to widespread belief of medical officers, particularly in the

forward areas. Inasmuch as the total care of a casualty is the function of many medical officers at several widely separated hospitals in the chain of evacuation, observations on the incidence of infection were necessarily difficult. The impressions of the medical officers regarding this subject were usually limited to the level at which they worked.

Our tour afforded the opportunity of making initial observations on wounded personnel at the MASH level as well as subsequent observations on the same patients in many instances at the Evacuation Hospital and Tokyo General Hospital levels. These observations were very revealing and indicated that the incidence of infection varied considerably at each level.

At the MASH level, clinical evidence of infection was less common and was limited to instances of peritonitis, retroperitoneal phlegmon, and occasionally, necrotizing infections associated with large areas of devitalized tissue. In most instances of wounds other than penetrating wounds of the abdomen and head wounds, normal evacuation of the patients occurred from the MASH level 2 to 5 days after injury, depending upon the flow of casualties. During this period a great majority of wounds were covered with dressings or casts preventing close observation of the area of injury.

When the same patients were examined at the Evacuation Hospital level, however, an entirely different idea was obtained as to the incidence and types of infection. For example, it was possible to carefully inspect 93 patients with a total of 128 wounds at the 11th Evacuation Hospital on 5 June 1953. The cause of the wounds was previously described under item 4*b*. The area of the wounds and the incidence of infection observed are shown in table 1. Of the 128 wounds,

Table 1. Area of Wounds and Incidence of Infection

Area and type of wound	Number of wounds	Infection			
		None	Slight	Moderate	Severe
Penetrating wounds of abdomen	8	2	1	4	1
Thoracic wounds	4	2	1	1	0
Neck	1	1	0	0	0
Upper extremity	45	25	8	11	1
Lower extremity	55	32	10	11	2
Buttocks	10	7	2	0	1
Perineum	2	1	0	1	0
Head	2	1	1	0	0
Burns	1	0	0	1	0
	128	71	23	29	5
Percent		55. 4	17. 9	22. 6	3. 9

15 were compound fractures of either the upper or lower extremity. Of the 15 compound fractures the presence or absence of infection was unknown in one. The casts were removed in every instance. No clinical evidence of infection was observed in five of these patients, slight infection was present in three, moderate infection in five, and severe infection in one.

Slight infections were interpreted as those having localized stitch abscesses, localized areas of cellulitis, temperature levels of 99° F. or less, and little or no exudate. Such infections were of no practical significance. *Moderate* infections were interpreted as those with temperatures of 100° to 102° F., evidence of actual wound suppuration with surrounding cellulitis, or localized myositis with discoloration of the muscle and herniation of the muscle through the incised fascia. *Severe* or *serious* infections were those in which there was evidence of extensive local infection with marked general manifestations of infection. Temperature in these cases usually varied between 103° and 104° F.

In the case of penetrating wounds of the abdomen or thorax, patients with slight infection were those with minimal clinical evidence of infection in the wound or the surgical working incision, and febrile response after the fourth day of 99° F. or less. Those with moderate infection had localized areas of exudation and cellulitis about the wound tract or the working incision, localized abscesses, and a temperature response of 100° to 102° F. Those with severe infection showed marked systemic reaction with high fever, rapid pulse, larger residual abscesses, persistent ileus, or a marked infection of the operative working wound or wound tract.

In analyzing this group of 128 wounds in this table, we see that 73.3 percent or approximately three-fourths of the wounds showed no evidence of infection or only slight infection which was of no clinical significance. Most wounds of this type came to successful delayed closure 4 to 7 days after initial surgery.

However, 22.6 percent of the cases showed moderate infection and 3.9 percent showed severe infection. One of the patients with severe infection died as a result of a proteolytic clostridial myositis. These figures may seem high compared to independent opinions of medical officers in the forward areas, but in reality they are commendable when one considers the difficulties in complete débridement which resulted from the multiplicity of wounds, the severity of injuries, the difficulties in adequate resuscitation, the immediate and delayed devastating effect on muscle by high-velocity missiles, and the number of vascular, bone and joint wounds.

The number of casualties arriving simultaneously at the forward hospitals may so overload the facilities of that hospital that surgical treatment on some of the wounded necessarily is delayed. In addition, patients with extensive injuries may have severe shock or other conditions which preclude early operation and which are delayed until adequate resuscitation has been effected. Moreover, patients may have multiple wounds and treatment that necessarily may require staging because of deterioration while the patient is under anesthesia or in recurrent shock. Under such circumstances, it must be remembered that the threat of infection exists in all wounds and that this threat increases with time between wounding and definitive surgery. During the period when the Chinese took Sandbag Castle for 40 hours, a time lag between injury and definitive treatment was temporarily increased. At this time, Lindberg showed that 11 patients who were in shock had positive cultures for Clostridia. Since that time there has been no appreciable increase in the time lag and the incidence for positive cultures of Clostridia was quite low although Colonel Lindberg had noted five or six positive cultures in isolated wounded soldiers.

Penetrating Wounds of the Abdomen

In penetrating wounds of the abdomen, infection is still an important complication. At the MASH level information was obtained from the medical officers that peritonitis as a cause of death had been seen very infrequently and that although the defense against bacteria had been broken by the injury, early treatment and antibiotic therapy had proved very efficient in preventing or controlling infections. At this level we saw 10 patients with abdominal or thoraco-abdominal wounds and early signs of postoperative peritonitis. Two of these died It would be impossible to say, however, that peritonitis was the cause of death in these.

At the Evacuation Hospital we obtained similar information regarding the infrequent incidence of peritonitis following casualties previously operated upon for penetrating wounds of the abdomen. However, careful examination of 31 patients with penetrating abdominal or thoraco-abdominal wounds at the Evacuation Hospital level proved that infection is still an important complication in these injuries. These patients were seen 4 to 14 days after laparotomy and all but two showed residual evidence of infection. Two had proven subphrenic abscesses and severe toxemia; three had serious wound infections with dehiscence in two; retroperitoneal or paravesical cellulitis coexisted in three others; paralytic ileus persisted after the fourth day in 20 percent of the cases. The temperature varied from 100.2° to

103° F. and the WBC varied from 14,500 to 21,000 with 93 percent polys in these cases. Two of the patients still had continuous gastric suction 10 and 16 days postoperatively for "intractable ileus" which undoubtedly was due to active infection.

Because of the insidiousness of intra-abdominal infectious complications and their lack of local signs, they were often unrecognized until the condition was far advanced. It was apparent that all medical officers should become familiar with the masked or obscure signs and symptoms of postoperative peritonitis.

When penetrating abdominal injury was complicated by anuria, spreading peritonitis was common. Similarly, when definitive surgery was instituted late, peritonitis was already present and often severe. Retroperitoneal hematoma with contamination was also a serious complication unless treated early and drained adequately.

Another source of information regarding postoperative peritonitis was found in the pathology records of autopsies at the 11th Evacuation Hospital. The records of autopsies done between February 1952 and April 1953 revealed 25 with penetrating wounds of the abdomen or abdomen and chest with generalized peritonitis, and 12 of these had undrained and large intraperitoneal abscesses. These abscesses were as follows:

Subphrenic	3
Subhepatic	5
Pelvic	3
Multiple	1

Other evidences of infection in these 25 fatal cases were as follows:

Abscess of liver	1
Brain abscess	1
Wound infection	2
Phlegmonous cellulitis	1
Abscess of kidney	1
Abscess of heart	1
Empyema	3
Lung abscess	1

The causes of injury in these 25 cases were as follows:

Mortar	12
Artillery shell	5
Rifle	5
Machine gun	1
Vehicle accident	1
Trip flare	1

It is particularly interesting to note that all of these 25 patients had anuria and had been sent to the Renal Center for special treatment.

WEDNESDAY AFTERNOON SESSION

Compound Fractures

Compound fractures were still associated with many problems concerned with control of infection, especially when the lower half of the tibia and fibula was involved, arterial injury or expanding hematoma was present, the joint was involved or when débridement was delayed, inadequate or impossible.

At the MASH and evacuation hospital levels we saw relatively little evidence of infection in compound fractures. This was due to several factors including the short period of time after injury which had elapsed while patients were at these hospitals, and the difficulties in making direct observations because of encircling casts. At the 11th Evacuation Hospital, as noted on page 340, the cast and all dressings were removed from 15 patients with compound fractures of the extremities 4 to 7 days old. Inspection of 14 of these patients and their wounds showed slight infection in three, moderate infection in five and severe infection in one. Another severe and fatal infection developing in a compound fracture of the femur at this hospital was a case of clostridial myositis and anuria (page 347).

Inspection of the wounded with compound fractures evacuated to the Tokyo Army Hospital Annex revealed a different story. The incidence of infection in compound fractures of the tibia or tibia and fibula was very high. Evidence of acute or chronic infection was found in the majority of wounds, and the significance of the process was reflected in the number of cases with nonunion of the bone, sinus tracts, abscesses, active pus formation, or a lack of healing of the soft tissue. In all of the wounds with infection and incomplete healing, dependent through-and-through drainage had been established by a rubber tube approximately three-eighth inch in diameter inserted from the depth of the wound through a small stab wound to the undersurface of the leg. This kept the wound dry and free of pooling of the exudate. In addition, acetic acid compresses were routinely applied to these wounds to discourage the development of green pus.

In two patients recently evacuated from the Korean front to the Tokyo Army General Hospital Annex, careful examination of the wound was done. Although the greater part of the surface of both wounds looked clean and bright red, a discolored and boggy area of muscle was found in each. Neither patient had a temperature above 100° F. orally, but it was demonstrated that a deep abscess was present in each wound and that thick gray foul-smelling pus, necrosis and liquefaction of the muscle were associated with the abscesses. Cultures and smears were taken and sent to the 406th Medical General Laboratory. Smears of this pus showed a mixed bacterial flora and numerous large gram-positive bacilli with square ends.

Inspection of a large ward filled with casualties having compound fractures of the femur was then made possible. Compound fractures of the femur in all stages of healing were seen. Some had completely healed, some had bony union and residual soft tissue infection including abscesses or sinus tracts, and a few had nonunion and active infection. Acetic acid dressings were commonly used in these wounds on this ward, also. The officers at this level indicated that the incidence of infection was high, but that, generally speaking, infection did not prevent satisfactory healing from occurring in fractured femurs, but that the period of morbidity was probably increased.

The case of one patient with a compound fracture of the femur and a persistent hemolytic *Staph. aureus* septicemia seen at this hospital on 25 May 1953 was of particular interest. Injury had occurred on 6 April 1953, but no débridement had been done because of his severe shock and subsequent anuria. In mid-April he developed the septicemia, thrombophlebitis at the site of a venous cutdown, and anuria. He was "dialysed" at the Renal Center of the 11th Evacuation Hospital on two occasions. His infection persisted in spite of treatment with all of the available antibiotics.

Examination of this patient revealed his temperature to be 104° F., pulse 136, and respiration 28. An unhealed compound fracture was being treated with balanced traction and severe local infection was present. Although there was no evidence of induration in the tissues of this thigh, a large abscess was easily demonstrated with pooling of a large amount of bloody pus. Further examination revealed septic embolic phenomena with petechiae of conjunctivae, bilateral areas of pneumonitis, splenomegaly and pericarditis. The hemolytic *Staph. aureus* cultured from the abscess and blood stream was resistant to penicillin, aureomycin and terramycin. It was sensitive to chloromycetin and erythromycin and slightly sensitive to bacitracin.

We were impressed with the fact that this patient had an extensive infection about the compound fracture with liquefaction of muscle and pooling of pus which had gone unrecognized and untreated surgically for a period of approximately 45 days. This case was presented to the Staff of the Tokyo Army General Hospital and discussed thoroughly. It was recommended that the patient be treated vigorously with erythromycin and that his abscess be promptly and thoroughly drained.

Clostridial Myositis

We were particularly interested in the incidence of clostridial infections in war wounds. Reports on this subject made previously and given to us indicated an extremely low incidence of clostridial infection in Korean casualties.

WEDNESDAY AFTERNOON SESSION

The reports of Lieutenant Gordon D. Lazerte which we reviewed at the 406th Medical General Laboratory were based upon examinations during 1952 of the following:

1. All amputated extremities submitted to the 406th Medical General Laboratory in Tokyo from hospitals in the Tokyo-Yokohama area;
2. All autopsies and most surgical specimens in that Theater.

This report left certain gaps in our knowledge. *Extremities removed at initial surgery* in forward hospitals were not included but had been disposed of locally. However, limbs removed 3 to 60 days after injury were handled as laboratory specimens. His study was concerned with 108 amputated extremities from 104 patients wounded in Korea. The extremities involved were as follows:

Upper arm	9
Disarticulation of elbow	1
Forearm	5
Hand	2
Total—Upper extremity	17
Disarticulation of hip	1
High thigh amputation	1
Middle or lower thigh	38
Disarticulation of knee	3
Amputation of lower leg	45
Transmetatarsal amputation	2
Unknown	1
Total—Lower extremity	91

Lazerte selected certain sites for histologic and bacteriological study and attempted to correlate these with clinical findings. The sites chosen included those of the original battle wounds, muscles distal to the battle wounds, and muscle compartments proximal to the battle wounds. Blocks of tissue were studied with hematoxylin and eosin and Goodpasture stain.

The causes of amputation were interpreted as follows:

1. Ischemic gangrene, or bland necrosis, although infection was a frequent complication;
2. Destructive trauma, in which the patient's limb underwent such severe trauma that healing or function was not possible; and
3. Gas gangrene, a rapidly spreading infection of muscles caused by Clostridia and characterized by great swelling, pain, and effects of "lethal toxins."

In one case described by Lazerte, No. 27126, devitalized tissue with gas in the absence of toxemia and in the presence of *Cl. welchii*, *Cl.*

multifermentans and *Cl. sporogenes* was found. A diagnosis of gas gangrene was not made. The questions in this case were: (1) Was this an instance of localized clostridial myositis; and (2) Were these Clostridia nonvirulent and nontoxigenic strains or did the absence of blood supply diminish absorption of their toxins? In other words, was this growth saphrophytic because of low virulence of the anaerobes? These and several other questions arose during the study of this case.

In Lazerte's series of 108 amputations, there were 8 cases of gas gangrene occurring 2 to 7 days after injury. More than 50 percent of the remaining stumps amputated for ischemic gangrene or destructive trauma were complicated by infection. The results of bacteriological culture from these extremities were available in 72 cases. The aerobic bacteria isolated included the coliform bacilli, *B. proteus*, Staphylococci and various Streptococci varieties. Many species of anaerobic Clostridia were also found. The pathogenicity of the Clostridia in each instance was tested by guinea pig inoculation of the pure culture.

The anaerobes recovered from the 72 cases were as shown in table 2.

Table 2. Results of Bacteriological Culture

Clostridia	Gas gangrene, 6 cases	All amputation wound specimens, 66 cases	Routine culture of 204 wounds
Welchii	5 (83 percent)	54 percent	42 percent.
Novyi	1 (17 percent)	39 percent	3 percent.
Sporogenes	3 (50 percent)		
Aerofetidum	1 (17 percent)		
Multifermentans	1 (17 percent)		
Tetani		6 percent	
Sordelli		3 percent	
Unidentified	1 (17 percent)		

One of Lazerte's cases of typical gas gangrene showed only the presence of sporogenes. Wineburg in 1918 reported two similar cases.

In a personal communication, Lieutenant Lazerte also noted that he found one case of fatal gas gangrene in 324 autopsies done on patients who died in hospitals as a result of battle wounds.

Discussions with the staff at the 46th MASH indicated that the incidence of gas gangrene was approximately 1 per 1,000 cases. Consultations with the staff of the 43d MASH revealed that 1 of 71 patients undergoing major arterial repair subsequently developed gas gangrene.

On the other hand, one of the great problems confronting this group as well as other surgical teams was muscle breakdown and liquefaction by compartments after successful arterial anastomosis and repair. The anterior compartments of the leg were most commonly affected. It was impossible to get adequate information as to whether or not proteolytic clostridial infection was wholly or in part responsible for previously reported cases.

In an effort to get more information on this subject long discussions were held with the Staff at the 11th Evacuation Hospital and the Artificial Kidney Center. During these discussions and others held elsewhere, it was evident that the staff members associated the signs and symptoms of pyogenic infections with clostridial infections. In other words, high fever, high WBC, purulent exudate, cellulitis, lymphangitis and lymphadenitis were expected. This, of course, was erroneous since severe and fatal infections often are associated with normal or slightly elevated temperatures, no purulent exudate, but profound toxemia.

One severe and fatal case of clostridial myositis was found at the Renal Center at this hospital among the 93 casualties examined on 5 and 6 June 1953. Inasmuch as this case had been unrecognized before, it is presented here in detail.

J. B., Canadian airman: This man was accidentally injured at 2100 hours on 25 May, receiving a gunshot wound of his left thigh with a 303 rifle with a muzzle velocity of 3,600 feet. He received a compound cominuted fracture of the femur through the lower third. The wound of extrance was at the left patellar area and the wound of exit was through the perineum. When seen at the battalion aid station, this patient was in shock. He was given 2,000 cc. of dextran solution and 500 cc. of plasma within 2 hours. At the end of that time his blood pressure was 95/50. He was then sent to the Norwegian MASH and at 2:50 a. m. on 26 May his blood pressure was not obtainable. At 0400 his blood pressure was raised to 90/60 following the administration of six units of blood. Operation was done from 6:30 a. m. to 11:15 a. m. consisting of extensive débridement of the medial aspect of the thigh, arterial graft done by Lieutenant Colonel Paus, and débridement of the knee joint. During this period he received a total of 17 pints of blood, making a total of 23 units of blood and 2,000 cc. of dextran. He was also given 10 cc. of calcium gluconate.

On 27 May, the following day, his blood pressure was normal, but oliguria developed. The patient's temperature at that time was 98.6–99° F.; no blood counts were recorded. On 28 May, the foot was noted to be cold and blue and amputation was considered. The skin color was good to the middle of the leg. A sweetish foul odor became obvious and "venous" bloody discharge without gas bubbles was noted

emanating from the wound through the cast. He was sent by plane on 29 May from the Norwegian MASH to the 11th Evacuation Hospital in Wonju. The fluid intake at the Norwegian MASH had not been recorded. When he arrived at the 11th Evacuation Hospital, his temperature was 99.2° F. rectally, his pulse 100, his blood pressure 130/80, and the patient was drowsy and thirsty. His WBC was 20,400 with 80 percent polys and 13 percent stabs. The RBC was 2.9 million, with 8.9 gm. hemoglobin. The hematocrit was 26. The cast was soaked with blood, and when it was removed, much clotted blood was found within the lumen of the cast and within the cast itself. An estimated 4,000 to 5,000 cc. of blood was lost in this manner.

On 30 May, the patient had been taken to the operating room and the cast was removed. A long linear medial incision was noted. The leg was markedly swollen and the sheet wadding had not been cut through when the cast was cut originally at the time of its application. The skin on the underside of the thigh was devitalized and showed numerous blebs on its surface at least 3 cm. in diameter. These were filled with clear serous fluid. The tops of the blebs rubbed off easily. The "packing" was taken out. The muscles were found to be edematous and herniated through the incision. The muscles were very dark in color and appeared nonviable and friable. They did not contract when pinched. Biopsies and cultures were taken. Muscle bellies were swollen to almost two or three times normal.

It was the opinion of those who saw the dressing that large masses of muscle were devitalized and infected. A guillotine amputation was done in the midthigh on 30 May and bleeding vessels were found to traverse the devitalized muscle bundles.

On 2 June the patient's temperature rose to 103.4° F. rectally, and the patient was placed on the artificial kidney for 6 hours. During this period he had a chill and again a rise in temperature to 103.4° F. His white count at that time was 22,900, and on 5 June, the white count was 24,000. He had been receiving 600,000 units of procaine penicillin b. i. d. and 0.5 gm. of streptomycin every 12 hours.

Date	Hematocrit	Blood transfusion (cc.)	Hemoglobin
30 May	25	1, 350	No determination made.
31 May	24	800	No determination made.
1 June	31	400	No determination made.
2 June	30 (Dialyzed)	400	No determination made.
3 June	16	2, 500	No determination made.
4 June	21	375	7.6 gm.
5 June	26	1, 025	9.2 gm.

His temperature rose to 104° on the morning of 3 June and fell to 102° on 4 June. Temperature on 5 June varied between 100° and 100.4° F. rectally.

Following dialysis the patient bled into the stump and the smell of sour decomposing muscle was obvious.

Two blood cultures taken on this patient were negative; the urinalysis showed scanty urine containing many red blood cells. No blood volume studies were done.

Realizing the significance of the odor on this patient when I saw him in making rounds, I requested of Colonel Seymour, Major Meroney, and Captain Sako that the dressing be removed for inspection of the wound. The wound was found to be extensively infected and covered with a grayish-green, extremely foul-smelling exudate. The muscle was dark brown in appearance in some areas and light tan in others. The muscle was so edematous that it herniated out of the area of incised fascia and through the amputation stump.

In addition, the patient was extremely lethargic and presented the typical picture of an extensive and overwhelming clostridial myositis. These facts, diagnostic of clostridial myositis, were pointed out and it was decided that the patient should be immediately taken to the operating room and an attempt made to remove all of the devitalized and infected areas of myositis as a last desperate effort to save the life of this moribund patient. His blood pressure at the time was 90/60 in spite of a continuous infusion of blood. Three intravenouses were started, one in the leg and one in each arm. Blood was administered continuously in one, and 5 percent glucose with saline in the other. As rapidly as possible, the wound was carefully inspected. The infection, devitalization and proteolytic digestion of the muscles were shown conclusively to follow the muscle compartments. Areas of necrotic, infected and devitalized muscle were adjacent to other areas of vital muscle.

As rapidly as possible, the infected areas of muscle were excised since amputation was impossible, the infection having spread along the iliacus and soleus muscles and onto the abdominal wall through the perineum. During the period that the areas were excised the patient's blood pressure gradually fell and in spite of all types of resuscitation, cardiac arrest occurred. The chest was immediately opened and cardiac massage carried out for 45 minutes. It was only temporarily successful in reestablishing cardiac beat. On four occasions, the heart started to beat but soon stopped in dilatation. Sections of muscle were removed for pathological study and given to Captain Blake, the pathologist, at the 11th Evacuation. Other pieces of muscle were removed from this patient and placed in deep meat media. Half of these were given to Captain Blake for culture and the other

pieces were retained by me and taken back to the United States for culture and study in order to identify the Clostridia present in this extensive proteolytic infection.

Subsequent cultures in the Surgical Bacteriology Laboratory of Cincinnati General Hospital revealed the presence of two Clostridia, one of which was intensely proteolytic, resembling but not identical with *Cl. sporogenes.* The other was a virulent *Cl. perfringens.*

After the personal observation of this overwhelmingly severe and fatal clostridial myositis, a search was made for other similar cases in the autopsy records of the preceding year at the 11th Evacuation Hospital. Twelve cases were found which appeared to have been clostridial infections.

1. *C. W. S.*, who was seen in the artificial kidney ward at the 11th Evacuation Hospital. He was injured on the 10th of May at 0800 by mortar fire. He received a wound in the left flank which injured the left spleen, kidney, aorta, right common iliac artery. He also received a wound to his leg. He was operated on at the 44th MASH at 10:45 a. m. His spleen and kidney were removed on the left and his aorta was repaired. Previous to operation he was seen at the divisional clearing station where he received 200 cc. of albumin and 100 cc. saline. He was in shock with a blood pressure of 60/40 which then dropped to 0/0. He was given 2,000 cc. of blood rapidly and his blood pressure rose to 100/60. During operation at the 44th he received an additional 4,000 cc. of blood making a total of 6,000 cc. up to that time. During the operation as the wound in the aorta was explored, the patient developed uncontrolled hemorrhage and went into profound shock. A foreign body was removed from the common iliac artery. Surgery was completed at 1300. Fasciotomy was also done at that time. During the next 24 hours his pressure varied between 100 and 140 systolic, although he was maintained on levophed, taking a total of four ampules. He received 3,000 cc. more of blood throughout the afternoon of the first postoperative day. At that time his hematocrit was 60 and his serum showed hemolysis.

During the first 3 postoperative days, he excreted a total of 200 cc. of dark bloody urine. There was no mention of fever on his record. His hematocrit was 57, his WBC unknown.

He was admitted with pulmonary edema on 14 May to the Renal Center. Amputation was done on 16 May, 2 days after admission. At that time it was noted that the muscle bulged through the fasciotomy excision of the lower leg. The muscle was discolored, cooked and brownish in appearance. A watery discharge with an extremely foul sour odor emanated from the muscle wound. This odor, according to Captain Sako and Major Meroney, was similar to, if not identical with, the odor on J. B. who was also on the kidney ward.

A below-knee amputation was done. The muscle was found to be infected and no bleeding occurred.

The patient underwent three dialyses on the artificial kidney. No cultures or biopsies of the wound were taken inasmuch as the changes in the leg had been considered to be due to trauma rather than infection.

The appearance of the wound, the limitation of the infection to the muscle bundles, the spread of the infection along the muscle areas, the profound toxemia, the falling red blood count and hematocrit indicated that this case was also an instance of the proteolytic type of clostridial myositis in all probability.

2. *C. Y. K.*, who was injured 11 January 1953 with an artillery wound of the chest, abdomen, right forearm, and right buttock. A severe infection developed in the buttocks with muscle necrosis, edema and a very foul odor from which Clostridia were isolated.

3. *T. B.* was wounded on 3 May as a Marine in action. He received a severe wound of his thigh caused by an exploding hand grenade or mine. A compound comminuted fracture of the right femur developed and the patient was thrown into deep shock. He received 9 pints of blood preoperatively and 5 pints of blood during the operation. The popliteal vein and artery were divided and amputation was done. Postoperatively, he developed shock and an arterial transfusion was required followed by further transfusion of blood intravenously; 300 cc. of blood was given intra-arterially.

This patient was anuric for 19 days after which he excreted 1,000 cc. of urine. By 8 May (fifth day after injury) the patient was severely uremic, developing an unusually rapid course compared to previous experience.

Those in attendance "found no evidence of infection" until 15 days when the temperature rose to 103° F. The blood culture became positive for *B. proteus*. On the seventeenth day the patient again went into shock. He was treated with aureomycin and chloromycetin. On the 21st day nausea and vomiting developed and he was treated with gantrisin. The patient then developed marked weight loss, going from 158 to 119 pounds. This started when he developed his infection. Patient was evacuated to Japan for further treatment.

4. *B. H.*, 21-year-old infantry private who was injured on 9 April 1953, sustained multiple missile wounds inflicted by a land mine. He had injuries to left arm, left thigh, left lateral chest, abdomen with perforation of left lobe of liver, right upper and lower extremities. Within an hour he was in the clearing station and had been given 1,000 cc. of blood and 500 cc. of albumin. He was transferred to the 44th Surgical Hospital and was given another 1,500 cc. of blood. Laparotomy, thoracotomy and amputation of left arm with débride-

ment of other extremity wounds were done. He developed renal insufficiency and was again transferred. In the next 6 days his course was remarkable because of his continued inadequate kidney function and some hypertension. However, on his sixth hospital day he developed fever and "secondary shock." The following day he had hyperpyrexia, WBC of 21,000 and died that day. Postmortem examination showed the "left calf to be swollen to twice its normal size and to be filled with dark red fluid blood which runs from the cut surfaces of the swollen, boggy, purple, mushy calf muscles." All other wounds showed greenish yellow exudate. It is not noted whether these wounds were foul-smelling or not.

5. *W. S.*, a 21-year-old infantry man wounded by mortar fire, 19 September 1952, with resulting traumatic amputation of left midthigh, penetrating wounds of lumbar region, right thigh, leg and foot, perforating wound of buttocks with perforation of colon. Five hours after injury he reached the collecting station where he was given 3,000 cc. of whole blood. Two hours later he was at the Mobile Surgical Hospital, arriving there with a blood pressure of 80/40. He was given 1,500 cc. more of whole blood to relieve his hypotension, then another 1,000 cc. of blood and was operated upon. Débridement of wounds, proximal colostomy, and high thigh amputation of the left leg were done. Following the operation he was in mild hypotension which was treated with another 1,000 cc. of whole blood, and because of oliguria he was transferred to the 11th Evacuation Hospital. On arrival there it was noted that all open wounds were foul-smelling and the left gluteal muscles were "necrotic from blast injury." During the next 11 days he was intensively treated for his oliguria. It is noted that there was "continued necrosis of buttocks and leg muscles associated with infection." On his fourteenth post-wound day he developed shock which would not respond to the usual measures plus 25 cc. of whole blood. He continued in shock and died on his sixteenth postoperative day. Autopsy showed the muscle tissue at the site of leg amputation and over both buttocks to be extensively destroyed and the remaining muscles to be hemorrhagic, soft and necrotic. The wound communicated with a "marked retroperitoneal pelvic hemorrhagic necrosis with abscesses."

6. *M. McG.*, a 27-year old master sergeant, wounded by artillery shell fragments, 30 March 1953. In the next 8 hours he was resuscitated with 5,000 cc. of whole blood, 1,000 cc. of dextran and operated upon. Laparotomy revealed no intra-abdominal injury. Multiple wounds of the right thigh were débrided, anastomosis of posterior tibial artery of the right leg was made, and treatment of a compound fracture of right tibia and fibula was given. The left leg had been traumatically amputated. During and immediately following sur-

gery, he was given 2,000 cc. of whole blood. Because of oliguria he was transferred to the 11th Evacuation Hospital. Three days later it was noted that his left leg amputation stump was grossly necrotic and disarticulation of the hip was necessary. This was associated with considerable shock. His course following this was hectic, manifested by alternating pleural edema and shock. He died in shock on the fifth post-wound day. Autopsy showed surface of the site of amputation of the extremity to be greenish-black, soft and foul-smelling.

7. *R. H.*, a 19-year-old Marine injured by mortar fire, 5 March 1953, with lacerations and abrasions of the right upper extremity, compound comminuted fracture of right femur, wounds with avulsion of left popliteal artery of lower extremity. He was treated by the débridement of his wounds, and arterial graft to his left popliteal artery. His treatment from injury to completion of operation included 13,000 cc. of whole blood. He developed oliguria on the second post-wound day and was transferred to the 11th Evacuation Hospital. Four days after transfer it was noted that he had hypertension and tachycardia. Three days after this he developed pulmonary edema and a week later it was noted that he had subcutaneous emphysema of his neck and chest. He died the following day, apparently in pulmonary edema. Autopsy revealed widespread necrosis of the gastrocnemius and soleus muscles of the left leg with hemorrhage along the fascial planes. There was marked subcutaneous emphysema of the chest, neck and mediastinum without any evidence that the lung was the source of the air.

8. *D. M.*, a 22-year-old infantry man injured 12 January 1952 by mortar fire. He had apparent exposure to cold for several hours, and not until the second post-wound day were his wounds débrided. Postoperatively, he had severe shock for 8 hours, for which he required 2,000 cc. of whole blood. It was noted on this day that he had beginning gangrene of both feet. Because of anuria he was transferred to the 11th Evacuation Hospital on his fifth post-wound day. There his temperature was only 97° and his blood pressure 140/100. He was delirious and grossly disoriented. His feet were purple, blotched and edematous, and gross edema of the subcutaneous tissue of his chest was detected. Eighteen hours after admission to this hospital he suddenly became dyspneic and died. Autopsy showed that the muscle of the chest wall exuded fluid; there were numerous open wounds over both legs to the thighs. His liver was grossly enlarged and purplish in color.

9. *W. C. S.*, 18-year-old, wounded 18 June 1952 by mortar fire. He was treated with 7 pints of blood prior to surgery on the date of injury. He had multiple wounds of both thigh and buttocks and a fracture of the left femur. Laparotomy was done revealing no

injury. Postoperatively he developed shock and no further débridement was done. He developed anuria and on his fifth post-wound day was transferred to the 11th Evacuation where he was dead on arrival. It was noted that he had generalized edema including his face. There was no comment as to whether the undébrided wounds were infected.

10. *R. B.*, 21-year-old soldier wounded 5 September 1952 by a land mine with multiple lacerations of the right leg and right hand. He was treated at the MASH 3 hours after injury. He required 5,000 cc. of whole blood to relieve his shock. Supracondylar amputation of the left leg and débridement of his arm wounds were done. He developed anuria and was transferred to the 11th Evacuation. At this hospital edema of the right forearm was noted. X-rays revealed fracture of the right radius with subcutaneous gas shadows. His course there was generally downward. It is noted that his thigh wounds continued to drain and that he developed a fever of 102° F., pulse 140. Investigation of his right arm revealed a large, foul abscess containing sanguino-purulent exudate extending from the wrist to the elbow. He continued to have delirium and signs of infection and died 13 days after injury. Autopsy showed all wounds to have evidence of infection with a foul-smelling exudate. Muscles of the forearm are described as soft, friable and purplish-red.

11. *A. K.* had an area of infected bone surrounded by an extensive amount of liquefied muscle excised in December 1952. *Cl. sporogenes* was cultured from the area of liquefied muscle.

12. *D. P.* was wounded 24 November 1952 by shell fragments with penetrating wounds of both legs, right arm and scrotum. Resuscitation and evacuation required 15 hours and 4,000 cc. of whole blood. All wounds were débrided. His course in the next 6 days was good. On the 30th of November it was noted that he had abdominal distention and tenderness, fever, and his WBC was 24,000. By 5 December his temperature was 104° F. He developed persistent hypotension and oliguria. He was transferred to the 11th Evacuation on 8 December. His shock state persisted as did his fever. No relief of his shock could be obtained. Autopsy revealed generalized peritonitis, lung abscess and clostridial myositis of legs.

Other possible cases of clostridial infection suggested by the description of the lesion only were:

1. *D. M.*, a 22-year-old soldier injured by shell fragments 27 September 1952. Injuries were multiple wounds around the anus, rectum, left groin, left calf, with a comminuted fracture of the left ischium. Operation was done 20 hours after injury during which he had been evacuated and had received 4,500 cc. of whole blood. Operation revealed rupture of the bladder and intact femoral vessels. Colostomy was done as was débridement of the calf wounds. During opera-

tion he had cardiac arrest, successfully treated. He remained unconscious from then until his death. He developed anuria and was transferred on his third post-wound day to the 11th Evacuation. On arrival his temperature was 102° F., pulse 130. It is noted that the inguinal incision was indurated. His anuria continued and his fever increased. His course was generally downward and he died on his fifth post-wound day. Autopsy revealed the operative wound of the left femoral canal area to contain a large abscess possessing grayish yellow pus and gas.

2. *R. D.*, a 22-year-old soldier injured by shell fragments 17 December 1952. During the next 5 hours he was resuscitated with 2,500 cc. of whole blood and evacuated. Operation revealed laceration of spleen, kidney, stomach, small intestine and colon through a wound in the left flank. During operation he received 3,500 cc. of whole blood and had persistent hypotension. He developed renal insufficiency and was transferred. At the hospital it was noted that his flank wound continued to drain pink purulent material. Blood culture on 22 December grew *Strep. fecalis*, *M. pyogenes*, *A. aerogenes* and Clostridia. He died 3 days later. Autopsy revealed a retroperitoneal space injection with necrotic, hemorrhagic material adjacent. The muscle tissue in the area was soft, friable and pale pink, and empyema was present also containing Clostridia.

3. *F. L.*, a 22-year-old private injured by multiple gunshot wounds 1 February 1953. He was evacuated to the MASH and there required 4,000 cc. of blood for resuscitation. Operation revealed laceration of the liver, perforation of the small intestine and cecum, compound fracture of the right femur. Cecostomy and repair of lacerations were done; his leg wound was débrided and casted. Postoperatively he had a recurrent bout of shock and on the second post-wound day he was evacuated because of renal insufficiency. He continued to have marked tachycardia and persistent hypotension. His temperature was 105° F. on his fourth post-wound day. He died on his sixth post-wound day. Autopsy revealed an abcess in the area of his liver wound, serosanguineous fluid in a wound of the right buttock in which area the muscle was necrotic and the skin was "macerated" and separated easily from the subcutaneous tissue. There was a hematoma in the right thigh-lateral area.

4. *F. H.*, a 23-year-old soldier injured by a trip flare penetrating his abdomen. His abdominal wall was severely burned and most of the small intestine was charred and necrotic. Resection of this portion of intestine was done as well as much of the abdominal wall. Postoperatively he developed oliguria. During his first to seventh post-wound days he continued to run fever, and on his eighth post-wound day because of continued oliguria, was transferred to the

11th Evac. On arrival there it was noted that he had fever of 101° F., that there was a subcutaneous emphysema over his lateral and anterior chest. His abdominal wound had profuse dirty watery discharge. His course was continually unfavorable and he died on his eleventh post-wound day. Autopsy revealed diffuse phlegmonous inflammation and necrosis of the muscle on the anterior abdominal and chest wall with subcutaneous emphysema.

5. *G. R.* was injured 27 March 1953 with a wound of the right buttock involving prostate, urethra, sigmoid colon and bladder and a wound of the right arm destroying 5 cm. of the brachial artery. He received 15,000 cc. of blood in the first 24 hours after injury. He developed oliguria and was transferred to the 11th Evacuation. On the ninth post-wound day he suddenly developed severe shock and jaundice, and the observer thought this was due to sepsis. His shock at first responded to blood transfusion and later to levophed temporarily, but he became worse and died on his tenth post-wound day. Autopsy revealed the arm wound to be covered with a blue green exudate with a sweetish odor. The muscles were soft and jelly-like. In the lower abdominal wall a large pocket of purulent material was found and adjacent muscle was soft, friable and hemorrhagic.

Other instances of localized septic liquefaction of muscle associated with putrid and butyric acid odor in wounds were seen at the 11th Evacuation, the 121st Evacuation, and the USS *Haven.*

It is difficult to compare the incidence of clostridial myositis in Korean casualties with those in World War II. DeBakey and Simeone during World War II summarized the cause of amputation in 3,177 cases in Europe and the Mediterranean Theater. Gas gangrene and other infections were responsible for 12 percent of the amputations. Destructive gangrene was responsible for 68.6 percent of the amputations. Lazerte's studies of 128 amputations done on 91 Korean casualties showed that gas gangrene was responsible for approximately 9 percent of the amputations.

During the North African campaign of World War II the incidence of gas gangrene was over 3 cases per 1,000 casualties (Heyningen: Bacterial Toxins. Charles C Thomas, 1950). The estimates given us by some medical officers that the incidence of clostridial myositis in the Korean campaign was 1 per 1,000 casualties seem to be too low. The difficulties in establishing the causal relationship of Clostridia to the foul-smelling liquefaction or necrosis of muscle with the limited information available are obvious. However, it is also obvious that clostridial myositis was more prevalent than previously believed. Furthermore, the proteolytic Clostridia seemed to play a relatively greater role in this theater than in other areas.

It is certain that clostridial myositis did occur, both as the diffuse type (gas gangrene) and as the localized type. Liquefaction of muscle in localized myositis by proteolytic bacteria, presumably Clostridia, seemed to be more prevalent than the diffuse myositis typical of gas gangrene.

e. The Relationship of Secondary Shock and Anuria to Sepsis. This subject was of special interest to us. Secondary shock developed 2 to 5 days after injury and usually followed operative intervention. It occurred most frequently in patients with abdominal injuries or with extremity wounds with large masses of muscle injury and necrosis. This hypotensive complication was characterized with oliguria or anuria, uremia, elevated potassium levels, extensive loss of weight, delayed or absent wound healing, a high incidence of severe infection, and a very high mortality rate of 80 percent or more. Other consultants have studied and reported on various aspects or manifestations of secondary shock. Our particular concern was the question of whether or not infection caused or contributed to the development of secondary shock.

This subject was reviewed at length with officers of the 406th Medical General Laboratory, the research team at the 46th MASH, the research team at the Renal Center at the 11th Evacuation Hospital, and with other officers. Reports of previous consultants and pathological and bacteriological data were made available and were studied by us. Microscopic sections of pathological specimens from autopsied patients were reviewed with members of the Pathology Department at the 406th Medical General Laboratory.

The time lag of 2 to 5 days between injury and the onset of secondary shock coincides with the incubation period of severe wound and peritoneal infections and is suggestive of the possibility of a causal relationship between certain infections and this condition. Captain Howard found that abdominal injuries were more apt to produce states of secondary anuria or oliguria. A review of the autopsy records at the 11th Evacuation Hospital between February 1952 and April 1953 revealed that severe infection unquestionably was present in practically all if not all of the patients dying of secondary shock. As previously noted (on page 342), there were 25 cases of generalized peritonitis resulting from penetrating wounds of the abdomen or chest and abdomen in the autopsy protocols of the patients with secondary shock and anuria. In addition, 12 of these had undrained large intraperitoneal abscesses. Other evidences of severe infection in these 25 fatal cases were wound infection in two cases, empyema in three, and abscesses of the liver, brain, kidney, lung and heart in one case each. Further study of the autopsy records during this same period showed 24 patients with severe infection of the wounds of the extremi-

ties. Twelve of these had evidence of necrotizing myositis, probably clostridial. These have been described previously in this report. Of the remaining 12 patients with extremity wounds the available information is less indicative of myositis, but there is the possibility that it existed in some. Other severe forms of infection were manifest in these 12 cases by chills, septic fever, leukocytosis, pathological evidence and the elevations of the temperature which ranged between 101° and 108° F. The temperature was in excess of 105° F. in 7 of these 12 cases. The WBC reports were sketchy but varied between 15,700 and 44,500 in those recorded. Pathological evidence of infection recorded in these cases included: pyogenic pericarditis, infected burns, cortical abscesses of kidney, *B. proteus* septicemia, lung abscesses and extensive cellulitis. The autopsy records of some of these patients are very sketchy and incomplete, and therefore it is difficult to draw any but general impressions.

The fact remains, however, that infection was present in most if not all of the autopsy records studied during this period. The question remains whether the secondary shock with anuria and the severe infection were separate complications of the injuries, whether infection actually caused some or all of the cases of secondary shock, or whether the secondary shock developed first and the infection was superimposed as a result of some overwhelming impairment of the body's defense against bacteria.

Our knowledge, based upon previous experience and studies of cases seen before, reveals several important observations which are pertinent to this problem:

1. Severe or uncontrolled peritonitis has been responsible for hypotensive states occurring 2 to 5 days after peritoneal contamination and attributed to "vasomotor collapse." Oliguria and anuria have been associated with the hypotension, and the mortality in such cases has approached 100 percent.
2. This peritoneal infection has been seen postoperatively in patients undergoing elective surgery of the colon or emergency operation for perforations of the appendix, peptic ulcers, as well as penetrating wounds of the abdomen. Often, one of the first manifestations of this severe postoperative infection is the sudden onset of hypotension.
3. Such peritoneal infections with septic shock have also been observed in individuals proved to have generalized peritonitis at autopsy in whom no operation had been performed.
4. Septic shock with hypotension has also been seen in cases of clostridial myositis, retroperitoneal cellulitis, urinary extravasation, septicemia and pneumonia. Most instances of

septic shock have developed 2 to 8 days after the onset of the infection.

5. Once this complication develops, death usually follows in 12 to 72 hours.
6. In gas gangrene or other forms of clinical clostridial myositis, rapidity of the pulse may progress to circulatory collapse and hypotension which may be abrupt, progressive and severe. As the pulse rate becomes increasingly rapid, the amplitude becomes steadily smaller.
7. Animals with experimental gas gangrene, studied at the University of Cincinnati, have shown evidence of circulatory collapse and septic shock preceding death. These animals likewise exhibit anuria.
8. Animal (dog) experiments with intramuscular injections of lethal doses of *Cl. welchii* toxin (1951) have revealed some very interesting post-injection data:
   (a) Fall in blood pressure over a 5-hour period;
   (b) Decline in the urinary output after the first hour with complete suppression after 4 hours;
   (c) Increase in blood urea nitrogen;
   (d) Diminished excretion of urinary chlorides;
   (e) Demonstrable histological alteration in the kidneys, visible after 2½ to 3 hours with diminution of circulating blood in the glomeruli and swelling of the glomeruli, also widespread vasocontraction of the cortical arterioles and capillaries;
   (f) Consequent functional alterations of glomerular and tubular action.

These observations indicate that secondary shock states can unquestionably be produced by severe and uncontrolled infection. They also give strong suggestive evidence to the possibility that sepsis has been a major and basic cause of the secondary shock occurring in Korea. In any event, this possibility is a real one which is worthy of intensive investigation.

f. Appraisal of the Influence of Antibiotic Treatment in the Prophylaxis and Control of Infections. The main reliance on antibiotic prophylaxis and therapeusis was procaine penicillin in dosages of 300,000 to 600,000 units with or without 0.5 gm. of streptomycin administered intramuscularly. Several studies indicate that this regimen was illusory and inadequate:

1. The absorption of intramuscularly administered antibiotics has been shown to be retarded and inadequate in shock by the individual investigations of the two authors of this report.
2. The blood and tissue levels obtained in shock by this route

and with this type of penicillin are significantly lower than those obtained with aqueous penicillin G given intravenously. Studies by Colonel Lindberg of the concentrations of penicillin in wounded tissues showed an average level of only 0.23 unit per gram, and in some instances no trace of penicillin was found.

3. The lower the concentration of penicillin in the tissues, the greater the number and variety of mixed bacterial species which were present.
4. In the study of injured limbs coming to amputation, Lindberg and Lazerte found active proliferation of bacteria in muscle biopsies in the presence of therapeutic concentrations of penicillin in the tissues. Although fewer numbers and varieties of organisms were present in the tissues with the higher concentrations of penicillin, none of the blocks of tissue tested were sterile. Although the reasons for the failure of antibiotics to halt bacterial action in dead tissue are not understood, the fact remains that this failure does exist.
5. Culture sensitivity studies revealed that approximately 40 to 60 per cent of the Clostridia isolated from wounds in Korea were not inhibited by this average concentration of 0.23 unit.
6. This therapeutic schedule does not prevent colonization of bacteria within wounds.
7. The data available support our impression that the combination of procaine penicillin and streptomycin as employed in Korea was successful in inhibiting infection only by the highly sensitive bacteria such as the hemolytic Streptococcus. On the other hand, it was inadequate against infections caused by mixtures of other less sensitive or resistant organisms. The course of peritonitis and proteolytic infections of muscle did not appear to be significantly influenced by this type of antibiotic treatment.
8. The presence of necrotic tissue in wounds rendered the antibacterial effect of the antibiotics inadequate.

g. Potential Usefulness of Clostridial Toxoid Immunization. Although it was apparent that clostridial myositis occurred more frequently in Korean casualties than was previously reported, it will be difficult to evaluate the potential usefulness of clostridial toxoid immunization in areas such as Korea until representative strains of Clostridia from actual war wounds can be studied with reference to their toxigenicity, virulence, hyaluronidase production, etc.

It seemed apparent, however, that the proteolytic action of Clostridia was more prevalent than the saccharolytic or toxic activity. This has posed a question as to whether or not a method of immuniza-

tion should be developed against digestion of muscles by the proteolytic enzymes of the Clostridia. A toxoid against the proteolytic activity of *Cl. histolyticum* is in the process of development at the University of Cincinnati now.

The possibility that clostridial enzymes may be related to secondary shock also needs investigation in a consideration of the future potential usefulness of clostridial toxoid immunization.

It must be remembered that the excellent record for the suppression of infections in war wounds in the Korean conflict was made under conditions which would not be operating in the event of an atomic attack, namely:

1. A relatively stable line.
2. A time lag between injury and definitive treatment of less than 4 hours.
3. Excellent surgical treatment by skilled surgical teams trained to do standard operative procedures.
4. Adequate supplies, materials and medical officers.
5. An intact chain of evacuation.

In the event of an atomic attack in such Oriental areas as Korea with destruction of medical installations, medical personnel and supplies, it would be impossible to treat the many thousands of casualties effectively. Under such conditions, the anticipated results would be:

1. Heavy clostridial contamination of wounds of all types in mass numbers. This high incidence of clostridial contamination in Korean casualties has been proven and is a reflection of the fertilization.
2. A necessarily long time lag of 24 to 72 hours or more between injury and treatment.
3. Medical and surgical treatment delayed until the end of this lag period and probably administered by less competent surgical teams and even unskilled personnel.

This long time lag, the inadequate supply of materials, the limited number of medical personnel, the delayed antibiotic therapy, and the impossibility of performing definitive surgery in mass casualties during the stage of wound contamination would almost certainly result in a very high incidence of wound infection and a conceivably high incidence of clostridial myositis. Under such circumstances gas gangrene toxoid immunization of troops before injury would be a major hope for the prevention or suppression of clostridial infections.

h. Recommendations. That the currently employed antibiotic regimen be changed as follows:

1. (*a*) Aqueous penicillin G should be given intravenously at the battalion level as soon after wounding as possible in

doses of 500,000 to 1,000,000 units every 8 to 12 hours depending upon the severity and multiplicity of the injuries. This may be given with other intravenous fluids.

(*b*) Streptomycin in doses of 0.5 gram should be given intravenously concomitantly.

(*c*) After 24 hours, if the patient's blood pressure is no longer reduced, the same agents should be given intramuscularly.

(*d*) After 72 hours the antibiotic therapy should be re-evaluated and changed as indicated.

(*e*) Streptomycin therapy should be discontinued after 5 days.

(*f*) If antibiotic treatment is indicated after 5 days, one of the broad-spectrum drugs should be considered.

(*g*) In cases of penetrating wounds of the abdomen and gross peritoneal soilage or in patients with extensive devitalization of muscle, terramycin, aureomycin, or chloromycetin should be given in doses of 0.5 gram intravenously at the time of initial surgery along with penicillin in the above-mentioned doses and continued as indicated. When blood pressure is normal and oral intake is possible, the broad-spectrum agents should be given by mouth in dosages of 0.5 gram every 4 to 6 hours. This therapy should be reviewed every 72 hours and varied or discontinued as indicated.

(*h*) In patients with septicemia every effort should be made to identify the organism and establish its sensitivity to the various antibiotics.

These recommendations were adopted by General Ginn and put into immediate effect.

2. Active surgical consultants should be made available in MASH Evacuation Hospital levels for teaching, consulting, and maintaining continuity of knowledge and surgical technic accumulated in previous wars and in research.
3. Emphasis should be placed on the fact that there is no substitute for frequent and careful clinical examination of the patients. This should be done particularly to detect masked or hidden infection.
4. There should be wider dissemination of existing knowledge to aid in the recognition of clostridial infections, hidden infections and infections masked by antibiotic therapy.
5. Careful investigation should be instituted to measure quantitatively the toxigenicity and pathogenicity of the Clostridia found in Korean war wounds. These results should be correlated with those previously made in other parts of the world.

6. The relationship, causal or complicative, of infection to secondary shock and anuria should be intensively studied. There is considerable evidence that uncontrolled peritonitis and necrotizing and spreading myositis are intimately associated with this syndrome.
7. Electrolyte imbalance in patients with severe infections warrants further study.
8. The cause of progressive anemia and hemodilution associated with extensive extremity wounds should be determined.
9. The fate of massive transfusion two or more times the total circulating blood volume in shock should be intensively studied further.
10. The possibility of residual toxic factors being caused by infection in patients with anuria after dialysis should be investigated.
11. Detailed clinical and laboratory studies should be made of patients with penetrating wounds of abdomen along a pattern similar to that established for neurosurgical and vascular injuries.
12. The recommendation of clostridial toxoid immunization is deferred temporarily pending comprehensive study of available data and aforementioned quantitative study of the virulence of Clostridia infecting muscle.
13. The relationship of infection to severe and progressive weight loss should be investigated further.
14. Practical means of completely sterilizing the artificial kidney apparatus should be sought.
15. The studies correlating bacterial flora of wounds and antibiotic sensitivity should be continued and expanded.

THERMAL BURNS*

LIEUTENANT COLONEL EDWIN J. PULASKI, MC

With every war the menace of thermal injuries seems to be increasing. The expanded use of gasoline in transportation of supplies and troops on the ground and in the air, the use of napalm and high explosives both for military operations and the destruction of cities, culminating in the nuclear fission weapons with their prospect of thousands of burns casualties—all these compel us to ask what has been learned from Korea, and what, if anything, could be done in the event of another outbreak of hostilities to improve the care of burns casualties.

In the past, the standard of treatment of burned patients in both civilian and military hospitals has often been poor, usually because, compared to many other emergencies, the management of such patients is more difficult. Few hospitals receive sufficient numbers of patients to attract and maintain the interest of the senior surgeons, or to keep the standard of treatment at a high level. More often than not, the care of the occasional burn injury patient admitted to the general surgical service of a hospital becomes the responsibility of a junior member of the staff. After costly delay in terms of healing time, chronic anemia, avitaminosis and secondary infection, the patient is then transferred to another hospital for plastic surgery, before or after previous trials of skin grafting.

In 1948 the Surgical Research Unit located at Fort Sam Houston, Texas, established a burns study program as its major activity. The immediate returns from the program at the Surgical Research Unit included revision of the Berkow scale for estimating the extent of the burn to the "Rule of Nines" formula, recognition of the Brown Electrodermatome as a simple, rapid, efficient means of cutting skin for grafting, demonstration of untoward reactions following infusions of Swedish dextran in human volunteers, and definition of the potentialities of the exposure principle of local care of burns.

The opportunity was afforded Major Artz and me in November 1950, to extend these observations and make others on Korean burns casualties at Tokyo Army Hospital, where special facilities were provided.

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One estimate is that thermal injuries constituted 2 percent of casualties in Korea admitted to hospitals. This is attested by the fact that in the 3 months of our stay, over 100 such casualties were admitted to Tokyo Army Hospital. In the overwhelming majority of instances (80 percent) the burns were accidentally incurred and were, therefore, preventable. There was no organized program for the care of burns casualties, for which reason the Unit was set up in Tokyo. Later another unit was established on the General Surgical Service, Osaka Army Hospital.

Principles of Treatment

1. *Early, Accurate Diagnosis.* It should be realized that any extensive deep thermal burn is a complex specialized problem. A brief history of previous illness, and a careful history of the details of the accident are essential. The latter may give clues as to the depth of the burn and the degree of the emergency which it presents. The minimum of information should include: (1) the possibility of respiratory tract burn; (2) the location, extent and estimated degree of surface burns, with a quick sketch of the burned area; (3) notation and assessment of associated injuries, and (4) a record of the agent causing the burn (fire, flash, chemicals, steam, electricity). Accurate diagnosis of the depth of the burn is not always possible on first inspection. A common tendency, even for the experienced observer, is to underestimate depth.* But the importance of diagnosing correctly burn depth lies in the fact that only thus can the magnitude of the problems facing the patient be appreciated.

2. *Diagnosis of Extent.* The "rule of nines" is a convenient measure. Each arm is 9 percent of body surface, the head is 9 percent, front of trunk 18 percent, back of trunk 18 percent, each leg 18 percent, and perineum 1 percent. The importance of correct estimate of extent lies in the fact that treatment will be partly guided by extent of the burn, and prognosis likewise.

3. *Triage of Burns Patients.* The risk of burns increases with the age of the patient and the body area burned. In general, the effects of burning are lethal in patients over 50 years of age with deep burns over 50 percent of the body surface. This trend has been expressed

*It seems preferable to classify depth in terms of partial thickness and full thickness. Partial thickness connotes first and second degree burns. A first degree burn, like a sunburn, is manifested by erythema and edema, small blisters and superficial desquamation, or the formation of serous bullae, under which is the familiar red, tender, painful, exudative skin. An obvious full-thickness burn can present as a firm, black or dark brown leathery eschar or a cold white marble or gray appearance with or without heavy desquamation and underlying pale pink or white dermis, or the presence of a network of thrombosed vessels within the corium. Such a burn is usually anesthetic to pinprick. It represents destruction of all epithelial elements and leads to separation of the eschar to an open granulating wound.

in a chart of mortality probabilities for different combinations of ages and body area burned prepared by the Birmingham Burns Unit—the mortality is shown as a decimal of 1.0. Zero denotes less than 5 percent chance of dying and 1.0 denotes a greater than 95 percent chance. For example, a young adult with a 50 percent burn has a 50 percent chance of dying.

From the foregoing a preliminary classification of the burn patient can be made:

1. Hopelessly burned (deep burns exceeding 70 percent of body surface).
2. Emergency cases.
   - *a.* Acute or impending respiratory emergency at the time of admission.
   - *b.* Chemical burns and ocular burns.
   - *c.* Extensive burns with concomitant visceral injuries, lacerations with profuse continuing hemorrhage, or compound fractures.
   - *d.* Patients with burns involving 15 to 70 percent of the body surface, who can be saved by vigorous therapy.
3. Patients with major burns in no immediate danger but requiring formal institutional care: partial-thickness burns of 10 to 15 percent of body surface, and full-thickness burns over 1 to 15 percent of body surface.
4. Patients for ambulatory treatment: burns less extensive than above, with no respiratory or ocular injury.

Plan of Treatment

A major cause of death after thermal injury is shock, and infection is the second most common cause. Scarring is the chief cause of deformity and disability. All these complications are easier to prevent than to cure. Shock may be prevented by early and adequate restoration of the fluid lost from the circulation. Clinical infection may be prevented by protection of the burn against colonization by bacteria by immobilization and by early grafting. Contractures and fibrosis may be prevented by early elevation, prevention of infection, correct positioning of the patient, and early débridement and grafting.

Immediate (Emergency) Treatment. Prevention of the complications of burning begins with support of blood volume, appropriate sedation, dressing and transportation to experienced hands. After noting the extent and severity of the burn, the clothing is examined for possible smoldering, which, if detected, is extinguished by dousing with water. Otherwise, it is probably better that the clothes be left

undisturbed until the patient reaches the hospital, and that the burn surface be covered wih a clean sheet or towels held in place with a bandage. No local medications of any sort are applied. If the burn involves the face or perineum, it is left exposed. The only indications for immediate treatment of the local wound are the chemical burn, for which antidotes are applied if available, and the corneal burn, for which a protective dressing is applied over the eye.

Sedation is best effected with barbiturates given intramuscularly. The amount of morphine, if administered at all, should not exceed 15 mg. intramuscularly in the first 4 hours, and it is contraindicated in the patient with acute or impending respiratory emergency. Most burns greater than 10 percent of body surface will require intravenous fluid replacement therapy. If these are available at the emergency station, an infusion is started, with whatever fluid is at hand. Albumin, plasma volume expander, dextrose in saline, saline, or dextrose in water may be used, in that order of preference. The fluid administered should be correctly recorded. The patient is evacuated as soon as possible to a hospital.

Therapy in the Hospital. As a burned patient is first seen, the presence of established respiratory emergency is diagnosed by rapid respirations and cyanosis. Crowing noises, gasping, frothing, coughing, or hoarseness may or may not be present. Pulmonary signs of ronchi, rales or atelectasis are also variable. In the presence of any or all of these, tracheotomy should be considered. In the presence of cyanosis, it should be done at once. If there is a burn of the face along with any warning signs of respiratory injury, it is well to remember that burn edema soon to follow will make tracheotomy difficult and it should be done at once. Although severe respiratory tract injury may be below the trachea, the tracheotomy facilitates bronchial suction and direct oxygen insufflation. Oversedation with depression of respiration and cough reflex must be avoided. Fluid therapy must be administered with caution because of the tendency to pulmonary edema.

When respiratory emergency does not threaten, the patient's clothing is removed, the extent of the burn is mapped out according to the "rule of 9's," an estimate is made of the patient's weight (most patients can tell their weight with accuracy), an indwelling plastic tube or needle is inserted under local anesthesia into an accessible vein, and a blood sample is obtained for hemoglobin and hematocrit determination as well as for typing and cross-matching, and finally, an indwelling Foley-type catheter is placed in the bladder for hourly measurement of urine volume and detection of renal damage as evidenced by albumin, casts and hemoglobin. The extent of the surface area

burned is a guide to planning the amount and kind of fluids needed. Renal output is the best guide by which to modify this plan.

There is general agreement that the main cause of burns shock is oligemia, chiefly due to loss of plasma. To the external loss into blisters and from open surfaces is added the edema of tissues deep to and surrounding those destroyed. Unlike patients with other forms of traumatic shock, in the burn patient fluid loss and threatened shock continue over a period of 24 to 36 hours. The aim of fluid replacement is to keep pace with this loss with a minimum of other disturbance. In addition, red blood cells are directly destroyed in a burn sufficiently deep to coagulate the dermal capillaries. There is also a delayed hemoglobinemia which may be due, either to intravascular hemolysis of cells not completely destroyed but rendered more fragile by some process, or to a hemolytic factor produced at the site of injury. In an extensive burn the blood loss in the initial phase amounts to 8 to 10 percent of the blood volume. The plasma loss approximates 0.5 to 1.0 cc. per kilogram of body weight for each 1 percent of body surface area burned. The loss of water and electrolytes into the burn, coupled with insensible and renal loss, approximates double or more the plasma loss. Unless these fluids are replaced, death from cell damage due to dehydration or tissue anoxia may supervene. If replacement is continuously accomplished, the continuing tendency toward shock will be avoided or relieved.

The treatment of burns shock is its prevention. This requires recognition of the cases which will develop shock, and the best guide is the extent of the burn as measured in percentage of the body area. Patients with less than 10 percent of body surface burned ordinarily will not require intravenous therapy. In these supplemental fluids by mouth may be given in the form of a solution containing 3.5 gm. of salt and 1.5 gm. of bicarbonate of soda dissolved in a quart of water, and chilled and flavored to taste. In more extensive burns, the following simple formula may be used as a starting guide to fluid replacement therapy, subject to extension upwards for children, and downwards for the elderly patient, the presence of pulmonary injury, and the involvement of more than 50 percent of the body surface.

Percent body surface burned $\times$ weight in kg. $\times$ 0.5 to 1.0 = ml. of colloid needed in 24 hours. The use of plasma carries with it the risk of jaundice. This risk makes it desirable to examine alternatives to plasma in the treatment of burns. Whole blood, albumin and dextran are suitable. Electrolytes and 5 percent dextrose in water should be administered in amounts sufficient to maintain a urinary output of no less than 30 ml. per hour. If whole blood or albumin are not used, it is wise to administer a liter of $1/6$ Molar lactate to correct acidosis as part of the electrolyte replacement. For example, the fluid re-

quirements in the first 24 hours for a 70 kg. man with a 30 percent burn can be illustrated as follows:

Whole blood, or plasma volume expander	$0.5 \times 30 \times 70 = 1050$ ml.
Electrolyte solutions	$1.5 \times 30 \times 70 = 3150$ ml.
5 percent dextrose in water	2000 ml.
	6200 ml.

These fluids are rationed so that one-fourth of the total amount is given in the first 6 hours after burning, the second one-fourth in the next 6 hours, and the remainder in the final 12 of the 24 hours. Oral fluid intake should be included in this calculation. It is reiterated that a common error is to overestimate the extent of the burn and to be overzealous in fluid replacement. If the urinary output exceeds 30 ml. per hour but not 60 ml., the amount and rate of fluid administration can be considered adequate. When the urinary output falls below this minimum, a test of the adequacy of fluid intake is the rapid intravenous administration of 500 ml. of 5 percent dextrose in water; if prompt diuresis follows, the fluid intake is cautiously increased.

Half the amount of fluid required in the first 24 hours is adequate to maintain the patient during the second 24 hours. Close observation of the urinary output and of the hematocrit will reveal exceptions, and the fluid ration should be altered as necessary. During the third 24 hours, spontaneous diuresis should be watched for and the fluid intake should be gauged accordingly. In general, oral and intravenous electrolyte therapy is not required after the first 48 hours. After the fourth day, the patient being stabilized, the urinary catheter should be removed.

Treatment of shock must be conditioned by simultaneous treatment of the injury under the following circumstances: (1) Chemical burns, which must be treated concurrently; (2) respiratory burns; (3) burns with extensive visceral injuries, lacerations with profuse hemorrhage and complicating fractures may require simultaneous treatment of these complications and the shock.

The local treatment of partial- and full-thickness burns is based on the triad of nursing care, resistance of the patient and rest of the affected part. By resistance of the patient, is implied avoidance of anything which might interfere with the reparative processes of the body. This means efforts are directed toward production and maintenance of a wound environment unfavorable to the growth of bacteria and favorable to wound healing. If the wound is grossly dirty, an effort is made to make it cosmetically clean without producing undue additional trauma. This is accomplished by general cleansing with a detergent and warm water, and débridement of loose tags of skin and blisters. Intravenous morphine analgesia usually is suffi-

cient for this purpose. Following cleansing, the whole area is carefully dried by soft towels. No local antiseptics or antibiotics are employed. The resistance of the patient is best aided by obtaining and maintaining an early dry surface which is kept cool. A moist warm exudate is a suitable bacterial pabulum favorable to the rapid colonization of the burns surface with microorganisms; conversely, a dry cool surface is less favorable for bacterial growth.

The dry surface, once effected, consists of a coating of fibrin, which, in the partial-thickness burn, then acts as a matrix for the ingress and coalescence of epithelium from the depths and margins of the wound. In the full-thickness burn it seals off the wound from invading bacteria and provides optimal conditions for the demarcation and separation of the burn eschar. Fibrin deposition is aided by rest and immobilization, and elevation to limit edema, whenever practicable. Once fibrin formation has been completed, the burn is no longer painful unless it becomes infected.

At present, there are two principal methods of bringing about a dry wound surface: the open or "exposure" method, and the absorptive or occlusive dressings method. In connection with the latter, it should be noted that the word "pressure" has been left out. The importance of absorptive dressings has often been erroneously attributed to their ability to prevent or minimize, by compression, the leakage of plasma from the burn surface by a dressing which does not need changing for approximately 10 days. Therefore, absorptive dressings should be sufficiently bulky to serve their purpose, so that fluid is blotted up and fibrin deposition effected. The "open" or "exposure" method results in a dry fibrin-covered surface. Formation of this coagulum is hastened by immobilization and a cool, dry environment, and is retarded by motion and the abrasive action of linens, etc. Once the crust has formed, which takes about 36 hours, the term open or exposure no longer applies. As epithelization takes place, the crust separates and can be lifted or cut away. Partial-thickness burns so treated heal in 12 to 24 days, depending on their depth and location.

A large burn dressing developed by the National Research Council is best used on encircling burns of the trunk and extremities and burns with complicating mechanical injuries. Burns of the hands require a smaller type of dressing which will permit elevation and splinting of the part in the position of function. A simple sterile covering is employed for minor burns of limited configuration. If such materials are unavailable, or in short supply, burns of moderate extent may be covered with clean, dry, freshly laundered or sterilized linen or toweling loosely kept in place by a bandage.

The principal indications for the open method are: uncomplicated burns of the face and the perineum and profile burns so located that

positioning will permit free access to the circulating air and recumbency of the patient on the unaffected side. Partial-thickness unilateral burns of the hand have also been successfully treated by the open method; however, full cooperation of the patient is required to maintain elevation and the position of function while the eschar forms. A combination of absorptive dressings and exposure has been employed in circumferential burns, such as those of the trunk and the thighs. This method carries with it the risk of suppuration in the areas which cannot be immobilized, where fibrin deposition is inhibited. In a disaster the closed method should preferably be used for all burns where complete eschar formation is unlikely to result following exposure.

The indications for the change of dressings may be categorized as either immediate or late. The immediate indications include: (1) excessive pressure as a result of faulty application or excessive edema formation, (2) soaking through of the dressings, (3) slipping, and (4) unexplained fever or pain. If none of these occur, the dressing is left in place for 7 to 14 days. At this time reassessment of the burn makes possible clearer definition of partial- or full-thickness involvement. If the burn is partial thickness in its entirety, it is redressed and removed after the fourteenth day, by which time re-epithelization should be nearly complete. If there are areas of full-thickness involvement, plans are made for skin grafting.

The defenses against infection are abetted in severe burns by prophylactic antibiotic therapy. Systemic penicillin or other antibiotic is given parenterally for about 5 days. In the severely burned patient, the initial dose is given in the intravenous infusion. The use of oral antibiotics early is inadvisable because of vomiting. Standard doses of tetanus antitoxin, tetanus toxoid, or both, are indicated. The prophylactic use of polyvalent gas gangrene antitoxin is not recommended. The use of ACTH or cortisone is also not recommended since recent observations indicate that fulminating spread of infection may attend their administration and, further, that their administration does not diminish the need of the burned patient for blood, colloid, electrolyte or water therapy.

By the end of 5 days the microorganisms colonizing a burn are likely to be drug-resistant. The concept of stopping antibiotics, waiting a few days depending on circumstances, and then reinstituting them, using a different drug or combination of drugs, has been practical and fruitful, particularly where the change of antibiotics may directly precede grafting. During the period of eschar separation the burn wound becomes increasingly painful as new nerve endings in the subcutaneous tissues become active receptors; this pain is aggravated by the presence of infection, motion or contact, until wound

closure has been secured. Dressings should be done under anesthesia, in the operating room. The golden moment is the time at which débridement can be done safely and at which skin grafts can be placed. The concept that a burned area must show "healthy" granulations in order to be "ready" for a graft is erroneous and invalid. In the burned patient the wound is ready for grafting when the eschar permits easy removal and clinical manifestations of infection are absent. In most burns these conditions coexist sometime after the second week.

Nutritional Care. After a severe burn the nutritional state is profoundly affected. The metabolic rate rises rapidly and may remain elevated for several weeks. The "reaction to injury" occasions an increased loss of nitrogen in the urine and this loss is greatest in previously healthy adults. Nitrogen is also lost from the burned surface, particularly in extensive infected burns. Lastly, demands for protein are increased by the processes of repair and healing.

At present, exact requirements for the various nutritional elements are not fully defined. From the third day of injury a planned increase in oral intake should be instituted until the patient's fluid intake is established at the desired level. Immediately after burning, patients with severe burns reject food or have poor appetite. Fluid feedings with or without nasogastric intubation are usually indicated. Gavage feeding insures a measured caloric intake. Various formulae which provide a balanced food intake with an adequate number of calories are available for this purpose. An optimal intake is 3,500 calories, 450 gm. of carbohydrate and 250 gm. protein. Vitamins should be given parenterally with emphasis on vitamin C (up to 1,000 mg. a day). Blood transfusions to correct anemia are given as indicated. Tube feeding is continued until the patient's appetite is fully restored. Early muscle movement will increase the proportion of nitrogen retained from the diet and limit the process of bone decalcification.

Skin Grafting

The closure of the full-thickness burn by skin grafting should be initiated as soon as practicable. Surgical excision of the eschar is feasible when the area involved does not exceed 5 to 8 percent of the body surface and the risk of shock is not great. Other methods of management of the eschar, such as enzymatic débridement, are now under investigation.

The cutting of the graft is best effected by the use of some form of dermatome. The electrodermatome is especially suited for the casual operator because it will remove thin grafts, will not damage donor sites, takes grafts swiftly, and requires very little experience to insure

proficiency. The grafts required are of intermediate thickness, 10 to 15 thousandths of an inch. Such grafts take in the presence of a mild infection, except when the wound is colonized with hemolytic Streptococci. Intermediate-thickness grafts also leave better donor sites, which can be used for a second crop of skin after 21 days. It is recommended that skin in excess of the amount required to surface the burn be taken and stored in bottles containing 10 percent human serum or in gauze moistened with saline solution. These bottles are stored in the ice box at 5° to 8° C. Such grafts can be used up to 4 weeks after cutting. Antibiotics are given 48 hours before and after operation as a precaution against spread of infection. The agent chosen should be on the basis of culture sensitivity tests of the wound exudate.

Grafts are maintained for 48 hours by the plasma circulation. Thereafter, ingress of capillaries begins and is complete in 5 to 10 days, depending on the body site and the thickness of the graft.

If the graft was applied to a clean area, the dressings are left alone during this period, that is, usually for 7 days or longer. If they were applied in the presence of suppuration, dressings are changed after 48 to 72 hours, using extreme care not to dislodge the graft. The wound is gently cleansed and carefully redressed, using the strictest aseptic precautions. Nonadherent grafts and overlapping tags of skin are trimmed away at the time of the first dressing.

The burned patient who is treated well can usually leave the hospital in 3 weeks to 3 months, depending upon the extent and depth of the injury. If the patient has not been treated well by failure to institute efficient systemic treatment, failure to prevent infection, or failure to institute grafting procedures at the right time, one is confronted with the vicious cycle of anemia, infection and malnutrition, which prolong the treatment for months, increase disability and deformity, and enhance the drain on hospital time and personnel. Patient morale is badly shaken, for which frequent, painful and exhausting dressings and despondency over failure to make progress are contributing factors. Such patients require repeated transfusions, usually twice a week until skin cover has been provided. Efforts to correct hypoproteinemia must be vigorous. Combined parenteral and oral alimentation will be necessary. Control of infection is initiated in the operating room where a total body cleansing is given to the anesthetized subject, with liberal use of a detergent and water. Débridement is indicated if dead tissue remains. Body defenses are aided by the use of antibiotics topically and parenterally, based on culture sensitivity tests. Septicemia is a threat in these patients until complete skin coverage has been attained.

RECENT ADVANCES IN MEDICINE AND SURGERY

Plan for Treatment of Burns Casualties in a Major Disaster. The results of the experiment of setting up a Burns Treatment Center at Brooke Army Hospital and at Tokyo Army Hospital during the Korean action have been amply rewarding. It has been demonstrated beyond doubt that, provided patients are seen early after injury and a high standard of surgical and nursing care is given in suitable facilities, disability and complications can be prevented. In the event of another war, as a basis for discussion, the following suggestions are put forth:

1. A plan should be executed to provide a short training for a large number of doctors, nurses and corpsmen in the modern treatment of burns. This training should be started at once in the Army center now available, and should be extended as soon as other centers are organized. Surgeons should be taught the essential principles of preventive treatment of shock and infection, and simple technics of débridement and skin grafting. This force of partly trained personnel would form the nucleus in an emergency to direct others not so trained who would need to be recruited on the spot.

2. Establishment of Burns Specialty Centers in the theater of operations. Such a facility should have a sufficient number of beds to carry out its mission, but no more than 40 in one center. An adequate staff for 24-hour duty is essential if supervised shock treatment is to be carried out, as well as routine dressings and other ward work. The unit should have its own operating facilities, preferably one room for septic cases and one room for the care of clean cases.

An adequate shock room is necessary, preferably several individual rooms, which, when the incidence of burns is small, could be converted to isolation rooms. Efforts to combat infection during dressings changes envision the need for an operating room or its equivalent for older cases and another room for recent, presumably clean cases.

The treatment of burns is the responsibility of a team and not any one individual. It is full of problems which can be faced only by adequate staffing. The Brooke Center experience points to the wisdom of appointing an anesthetist, internist, psychiatrist, dietitian, bacteriologist, biochemist and physical therapist to work alongside the surgeon. Full recognition of the emergency nature of the treatment of burns and of the problems of the treatment of shock, control of fluid and electrolyte imbalance, nutrition, anemia, sepsis and psychiatric disturbances, will be sufficient to make a plea for a Burns Center so staffed justifiable.

THURSDAY MORNING SESSION

22 April 1954

MODERATOR

LIEUTENANT COLONEL GEORGE J. HAYES, MC

A REVIEW OF POSTMORTEM EXAMINATIONS IN COMBAT CASUALTIES*

FIRST LIEUTENANT JOSEPH G. STRAWITZ, MC

During a 10-month period in 1952 and 1953 a pathologist was assigned to the Surgical Research Team of Korea operating at the 46th Army Surgical Hospital. His mission was to supplement research activities of the team with information gleaned from postmortem examinations performed on victims of traumatic death previously treated at the hospital. Autopsies were also done routinely when death resulted from vehicular accidents, burns, medical causes and suicide.

This report deals only with 35 cases in which death followed treatment of wounds received in combat. Analyses of other traumatic deaths are deleted in an effort to bring emphasis to those cases which pose the greatest problems in management. Because of the relatively small number of cases presented, statistical significance cannot be attached to them. However, definite trends can be observed and some generalizations made.

The large majority of casualties were examined by the same prosector. Microscopic review and interpretation were carried out by several members of the Pathology Department of the 406th Medical General Laboratory. Clinical histories were recorded in great detail and frequently the prosector had observed the clinical course of the patient prior to death. Consequently, considerable consistency in examination and interpretation was possible.

Results

Table 1 lists the causes of death in 35 combat casualties. There is considerable overlap between the first three groups—irreversible shock, vital organ damage, and uncontrolled hemorrhage. Some cases with vital organ damage and others with uncontrolled hemorrhage showed changes consistent with those seen in irreversible shock. On the other hand, in a few cases classified as irreversible shock the patients exhibited uncontrolled hemorrhage during some period of their clinical course. Despite this overlap, the single major cause of death

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Table 1. Causes of Death in 35 Combat Casualties

Cause of death	Number of cases	Cause of death	Number of cases
Irreversible shock	11	Blast injury (lungs)	1
Vital organ damage	9	Fat embolism (cerebral)	1
Uncontrolled hemorrhage	6	Uremia (lower nephron nephrosis)	1
Bronchial obstruction	2	Subdural hematoma	1
Cardiac standstill	1	Cause undetermined	1
Myocardial infarction (traumatic coronary thrombosis).	1		35

was determined by considering all factors. The causes of death in the remaining cases were quite specific.

Irreversible Shock. Over the years there has been a great deal of controversy regarding the disturbed state of physiology called irreversible shock. Some investigators have even denied that such a syndrome exists. Recent thinking on the problem has implicated a number of etiologic possibilities. Hypoxia, bacterial invasion, tissue breakdown, psychological stress and other factors have been considered. They are difficult to evaluate in any single case since their nature is not well understood and methods of measurement have not as yet been developed. A complex etiology is suspected in this series, since survival was observed in other cases with equal and greater degrees of tissue destruction and organ damage.

Experiments subjecting dogs to prolonged periods of hypotension have shown that death ensues despite adequate blood volume replacement. Although the period of hypotension required to produce death in humans is not known, there must be a time limit from which there is no return to normal.

Table 2 shows median values for the evacuation time, survival time and blood volume replacement in 11 cases of irreversible shock. On the basis of the prolonged period of hypotension, the severe state of clinical shock and the marked degree of tissue destruction displayed in most instances, the clinical diagnosis of irreversible shock was made.

Table 2. Median Values, Evacuation Time, Survival Time, and Blood Volume Replacement in 11 Cases of Irreversible Shock

Evacuation time, wounding to MASH	Survival time, wounding to death	Total blood volume replacement
4 hours, 45 minutes	17.5 hours	9.5 liters.

Table 3 shows a tabulation of morphologic findings occurring in various combinations in irreversible shock. Petechial hemorrhages involving serous surfaces and mucous membranes are commonly thought to result from prolonged hypoxemia. Subendocardial hemorrhages are not infrequently seen and are peculiarly limited to the right side of the heart, as in the medical shock of hemorrhagic fever. The many differences in anatomy and physiology between left and right sides of the heart have been seized upon to explain this peculiar localization of hemorrhages. No positive explanation is available to date.

Table 3. Morphologic Changes in Irreversible Shock

1. Petechial hemorrhages—Serosal, mucosal (gastrointestinal).
2. Dilatation and engorgement—Vessels in abdominal and thoracic viscera, brain, striated muscle.
3. Pulmonary edema.
4. Pulmonary atelectasis—Focal and diffuse.
5. Dilatation of cardiac chambers with flabbiness of the myocardium.
6. Renal tubular changes consistent with lower nephron nephrosis (microscopic).
7. Lipoid depletion—Adrenal cortical cells (microscopic).
8. Fatty vacuolization—Heart muscle, liver, kidney (microscopic).

Intense congestion of all organs and striated muscle was a consistent finding. On section of lungs, liver, spleen or kidneys, fluid blood virtually poured out.

Microscopic examination confirmed the severe dilatation and congestion of all blood vessels. It is not surprising that large quantities of blood were used in attempts to maintain adequate arterial pressures in such expanded vascular trees.

Table 4 shows various degrees of pulmonary edema in 11 cases of irreversible shock. The majority show some degree and over half exhibited marked edema. The average blood volume replacement is shown with each grade of edema. There appears to be more edema in those patients most vigorously resuscitated. It must again be emphasized that these cases represent a very small sampling and should be evaluated in this light.

Table 4. Degrees of Pulmonary Edema Compared to Blood Volume Replacement in Cases of Irreversible Shock

Degree of pulmonary edema	Number of cases	Average blood volume replacement
No edema (below 500 grams)	1	2.0 liters.
Slight (500–700 grams)	3	4.8 liters.
Moderate (700–900 grams)	1	12.0 liters.
Marked (900 grams plus)	6	13.0 liters.

In classical descriptions, it has been suggested that pulmonary edema is a constant and integral part of the shock mechanism. Several factors may influence its development. It is certainly a common complication of renal insufficiency which frequently accompanies shock. Cardiac failure, as evidenced by gross flabbiness of the myocardium, dilatation of cardiac chambers and microscopic fatty degeneration of myocardial fibers, must play a considerable role in the formation of pulmonary edema. In a review of a large number of traumatic deaths, fat embolism has been shown not to predispose to this complication. It is difficult to assess the importance of overenthusiastic intravenous therapy.

Varying amounts of pulmonary atelectasis were seen in many cases of irreversible shock. In some cases, patchy areas were seen, while in others the greater part of a single lobe might be involved; this was usually basilar in distribution. These pulmonary findings may very well have represented agonal changes frequently seen in patients subjected to anesthesia, etc. In one case of the eleven, diffuse atelectasis was thought to be one of the principal factors causing death.

Congestion of striated muscle is listed as a morphologic finding in irreversible shock. This is particularly true of patients strenuously resuscitated with whole blood and fluids. Striated muscle composes a large part of the human body but is not often seriously considered at the postmortem table because of its somewhat hidden anatomical location. Yet a great part of the vascular tree is found in these large masses of muscle. The typical finding in examining large avulsive wounds was severe congestion with outpouring of blood and fluids at autopsy incision. Further studies are necessary to correlate this observation with the theory of blood sludging and pooling.

Renal failure is a universal finding in irreversible shock. The principal morphologic findings consist of heme casts within tubules and varying degrees of degeneration of the tubular epithelium. In larger series of cases these changes are found to occur after the first 24 hours of shock. In this series, all showed marked renal insufficiency during the clinical courses. Four of 11 cases showed morphologic changes consistent with lower nephron nephrosis. The remaining cases might have exhibited these changes had the time of survival been longer than the average 17.5 hours.

Dr. Tracy Mallory, in studying postmortem material from shocked patients during World War II, found a peculiar morphologic change in the viscera when the survival time was over 18 hours. With special stains, fat vacuolization was demonstrated in the heart, the central cells of liver lobules and the ascending limbs of Henle's loops. In the adrenal gland the doubly refractile lipid became depleted after the same time interval. From the fourth day onward in cases not com-

plicated by infection, a tendency to a return to normal could be demonstrated. Special stains were not carried out in cases presented in this report. However, Dr. Mallory's finding is an important morphologic demonstration of an intracellular response to injury produced by shock.

Vital Organ Damage. Nine patients died of vital organ damage not compatible with life. Seven showed extensive brain damage and two had direct cardiac involvement by shell fragments. The majority of patients survived for some hours.

Uncontrolled Hemorrhage

Table 5 shows a summary of six patients whose deaths were attributed to uncontrolled hemorrhage. All showed profuse bleeding from lacerated, large vascular channels. It appears in most cases that if adequate control of profuse hemorrhage had been possible early, death may not have occurred. The average evacuation time from wounding to hospital admission is considerably shorter than that seen in irreversible shock. Pulmonary edema is a less frequent finding.

Table 5. Summary of Six Cases of Uncontrolled Hemorrhage

Case No.	Evacuation time wounding to MASH (hours)	Total blood vol. replacement (liters)	Pulmonary edema	Site of bleeding	Survival time (hours)
1	5½	10.5	None	Laceration of pulmonary vessels.	11¾
2	3	0	None	Splenic rupture, laceration of lung.	3
3	2½	Total unknown 3.5.	None	Lacerated kidney, retroperitoneal and peritoneal hemorrhage.	18
4	4	18	None	Lacerated vena cava	17
5	1	6.5	Moderate	Lacerated dural vessels.	4½
6	1½	9.5	Moderate	Lacerated mesenteric vessels.	3½
Average	2. 9	8.5			9. 6

Bronchial Obstruction. An open airway is always a primary consideration in surgical cases in both military and civilian life. Two patients in this series died of bronchial obstruction. A simple amputation of a lower extremity was performed in one case with excellent chance of recovery. Aspiration of vomitus 15 minutes postoperatively was the cause of death. The remaining patient suffered a perforating gunshot wound of the lung with bleeding into the bronchial

tree and obstruction. This patient died shortly after hospital admission.

Cardiac Standstill. Cardiac standstill is a physiologic death which ordinarily is unaccompanied by morphologic changes. One patient with multiple avulsive and puncture wounds of all extremities died during surgery. Cardiac massage was performed without benefit. A moderate number of fat emboli were seen microscopically in small myocardial blood vessels. It is not known what influence they may have had on cardiac function.

Myocardial Infarction (Traumatic Coronary Thrombosis). The one case of myocardial infarction resulting from coronary thrombosis was a surprising finding. The patient, who suffered a puncture wound of the left lung from small arms fire, showed progressive cardiac failure during surgery. At autopsy, an antemortem thrombus was found in the lumen of the circumflex branch of the left coronary artery. Microscopically the myocardium exhibited degenerative changes. Although there was no myocardial laceration in the region of the left coronary artery, diffuse subepicardial and perivascular hemorrhages suggested that contusion and arteritis may have occurred from the marked pressure changes when the missile passed through the thorax.

Fat Embolism. Fat embolism has been recognized as a complication of trauma and fractures for many years. Different investigators have ascribed varying importance to it as a death-producing clinical entity. Captain Robert E. Scully has reviewed a large number of battle casualty autopsies and has shown that fat is found in the lungs in over 90 percent of cases and is occasionally seen in the kidneys (*1*). Cases of death resulting from fat embolism were rare in his review. The criteria for establishing fat embolism as a cause of death are a typical clinical history with neurologic findings and the presence of a moderate to marked degree of fat in the vessels of the lung, kidney and brain. Perivascular hemorrhages and necrosis in the brain are the usual findings in fatal cases.

The one fatal case of fat embolism in this series was classical. The patient suffered traumatic amputations of several extremities and numerous avulsive and puncture wounds. Preoperative resuscitation and surgery were uneventful. However, recovery from anesthesia was not complete and intracranial hemorrhage was suspected when the patient remained unconscious and displayed muscular twitchings. A craniotomy was negative. The patient died several days after wounding and postmortem examination revealed the typical morphologic findings of fatal fat embolism.

Blast Injury. In World Wars I and II injuries to the thoracic and abdominal viscera and to the central nervous system were observed

to occur as the result of rapid changes in the environmental pressure from air blast. When persons are exposed to the effects of nearby shell and mortar explosions, death may occur with minimal evidence of external injury. Hemorrhages and lacerations of the lungs, abdominal viscera or brain may occur. One patient in this series was close to an exploding mortar round and showed severe pulmonary hemorrhage, congestion, contusion and edema without perforation of the thorax. This patient was admitted to the hospital but died shortly afterwards with severe respiratory distress and hypoxia. A large shell fragment was found in the region of the left kidney.

Lower Nephron Nephrosis. One case of marked renal insufficiency resulting from a penetrating abdominal wound with multiple perforations of the small intestines was seen in this series. The patient died 6 days post-wounding in uremia. The morphologic findings were compatible with severe lower nephron nephrosis. There were numerous heme casts in renal tubules and marked degeneration of the tubular epithelium. A fibrinopurulent peritonitis was found at autopsy.

Subdural Hematoma. One patient had a subdural hematoma as a complication of a skull fracture. A very large subdural blood clot was evacuated. The patient died shortly thereafter with signs of increased intracranial pressure.

Cause Undetermined. In the one case in which a cause of death could not be established, the patient suffered a gunshot wound of the abdomen with laceration of the tail of the pancreas. The postoperative course was uneventful and the patient was ambulatory. He suddenly developed severe respiratory distress on the sixth postoperative day and died 12 hours later in vascular collapse. The clinical history was suggestive of pulmonary embolism, but the autopsy did not confirm this diagnosis. There were no significant findings to suggest a cause of death.

Summary

An analysis of 35 postmortem examinations in combat casualties dying relatively soon after wounding is presented. Irreversible shock, vital organ damage and uncontrolled hemorrhage constitute the major causes of death. Bronchial obstruction, cardiac standstill, traumatic coronary thrombosis, blast injury and subdural hematoma were found less frequently. One case of lower nephron nephrosis is described in a patient who died 6 days post-wounding. Although fat embolism is found frequently in the lungs of victims of traumatic death, it rarely is the principal factor causing death.

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PROBLEMS OF WOUND TREATMENT DURING THE EARLY PHASES OF THE KOREAN WAR*

COLONEL JOSEPH P. RUSSELL, MC

The sudden outbreak of war in Korea created an unpredictable and immediate need for field medical units. To meet this emergency it was necessary to "gut" every military hospital in Japan of all but a few of its medical personnel. Understaffed, skeletonized, field medical units were then rapidly formed and dispatched to Korea. Obstetricians, internists, pediatricians, general practitioners, orthopedists and surgeons alike found themselves at once responsible for the care of overwhelming numbers of seriously wounded battle casualties.

Despite the lack of unit training, shortage of medical personnel, and lack of comprehensive experience in war surgery, these units magnificently performed an almost impossible task. Their contribution is reflected in the lowest overall death rate in military hospitals ever recorded in any war.

This success was primarily due to the unified efforts of the Army, Navy and Air Force working jointly as an effective medical team, and to the selfless performance of each individual concerned. A highly coordinated medical supply system, operating through an unmolested base of operations in Japan, provided a profusion of modern equipment and supplies of excellent quality, including plenty of whole blood and a wide range of antibiotics. The development of helicopter evacuation, employment of MASH units in close support of combat, use of hospital ships as nearby floating hospitals, the wide use of air evacuation and development of specialized teams and treatment centers, all contributed to the overall lowered mortality. An effective preventive medicine program was responsible for the suppression of malaria and absence of epidemics, while the development of the armored vest and improved footgear further reduced the death and casualty rate.

While the general picture of medical accomplishment during the Korean war was one of steady improvement and advance, the histories of World Wars I and II and observations made during the Korean conflict reveal instances where all of us could have profited from know-

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ing more about, and applying the lessons learned, in previous wars.

In any national emergency many a capable surgeon, with ample experience in civilian surgery, will be confronted with treating multitudes of seriously wounded patients and may find himself uncertain and confused with new problems not ordinarily met in his practice. The current management of war casualties has been evolved throughout the years based on the wisdom, trials, errors and accumulated experience of hundreds of surgeons in preceding wars. Only by knowing and applying the broad policies and guiding principles established by those who preceded him can one avoid the repetition of serious and sometimes fatal errors.

In an effort continuously to improve the standards of war surgery, each medical officer must become familiar with the basic concepts, so that the priceless lessons of other wars need not have to be "rediscovered" in World War III. These principles refer not only to forward medical care and wound management, but to the time and methods of evacuation, the timing and place of operation and other problems of good medical service throughout the chain of evacuation.

Throughout the first year of the war it was evident that, when the initial management of the wounded had been guided by established principles, most of the patients presented no problem when they reached a rear area hospital and pursued an uncomplicated course. On the other hand, many of the serious surgical problems encountered at Tokyo Army Hospital resulted from lack of experience in war surgery, delay in, omission or inadequate application of, some principle at initial surgery.

In the early days of the war, patients often arrived at Tokyo Army Hospital within 3 to 10 days after wounding. Because of the limited number of beds and the unstable tactical situation in Korea, rapid evacuation of patients from forward hospitals became an absolute necessity and could not be deferred. The result was that the medical officer who performed the initial surgery had no way of following the subsequent course of his patient to determine the final outcome of his treatment. Since no complications had become manifest by the time the patient was evacuated, the surgeon might logically assume that his management of the case had been proper, and unknowingly develop a false impression which led to repetition of the same improper procedure in subsequent patients.

Rather than to be content with the fine record established in the Korean war it may be of value to cite examples wherein we did poorly, and how we may eliminate the same problem in another war.

Débridements were often incompletely done through inadequate incisions with the result that, during the early months of the war, the incidence of wound infections was extremely high. The faulty use

of Vaseline gauze did more harm than good. Some wounds were found tightly corked with a yard or more of Vaseline gauze which completely prevented drainage of the wound. These patients were febrile and quite toxic and on removal of the gauze plug it was common for a half pint or more of foul pus to gush and bubble from the depths of the wound. Besides damming the pus in the wound, the gauze packing had served as a splint which held the walls of the wound widely separated converting the wound into a cylinder with indurated, fixed walls which would not readily collapse. To avoid this condition thorough initial débridement should be done using bold linear incisions that will allow exposure of the entire wound tract for removal of foreign bodies and devitalized tissue. Good exposure will result by applying the old generalization that "the wound should be twice as long as it is deep." A few layers of gauze should be laid into the wound to keep the wound edges apart and allow the wound to collapse. Under no circumstances should the wound be plugged and propped open with gauze packing. Counter-incisions should be made if needed to provide dependent drainage.

An occasional case was seen early in the war in which débridement and primary suture had been performed. Some of these wounds healed without complication but the majority of patients developed wound sepsis with further loss of tissue and delayed wound healing. Although it may at times be tempting, primary closure should be avoided and employed only in certain instances, such as craniocerebral, maxillofacial and certain abdominal, thoracic and hand wounds.

Pressure sores over the dorsum of the foot and impaired circulation of an extremity were occasionally seen as a result of a tight cast which had not been split prior to evacuation. An extensive slough of the skin on the dorsum of the foot, due to traction applied to the bare foot, was seen in one case. To avoid these complications, all casts must be split completely through to the skin prior to evacuation. The shoe should not be removed when applying a temporary traction hitch to the foot.

The wisdom of open amputation was again demonstrated. Two badly infected pus-filled amputation stumps were due to a definitive type of closed amputation; both required further surgery with additional sacrifice of stump length. The open circular type of amputation has been found to be the safest for war surgery and should be used exclusively. The amputation should be performed at the lowest possible level, without regard for the final utility of the stump. The use of this type of amputation demands that skin traction will be continuously applied until the stump is healed or the patient evacuated. Failure to maintain skin traction results in retraction and fixation of

the soft tissue with protrusion of the bone and necessitates reamputation with sacrifice of addition stump length.

Transverse abdominal incisions were found to be bad in war surgery. While this incision may at first appear attractive because it can be developed to provide a wide range of exposure, it was followed by a high percentage of huge ventral hernias with extensive loss of abdominal wall. Some of these hernias were so large that satisfactory repair was unlikely. Another serious disadvantage of the transverse incision was evident when a torn segment of colon had to be exteriorized through one end of the operative incision because no other area was available laterally. Exteriorization of the colon through the operative incision is undesirable as it almost assures a badly infected exploratory wound. The vertical paramedian incision is preferable as it provides good exposure, is least liable to complications, and allows the colon to be exteriorized through a short laterally placed, separate incision rather than through the operative wound.

Because of fecal contamination in war wounds of the abdomen, varying degrees of infection of the exploratory incision were common, ranging from minor redness and induration in the usual case to frank suppuration, wound abscess, extensive fasciitis and slough in the rare instance. To minimize the effects of wound contamination and to prevent extensive loss of abdominal wall, the peritoneum and posterior sheath should be closed and the remainder of the wound loosely approximated with heavy through-and-through, wire stay sutures. The larger the wire, the better: 0.028 or larger wire gave the best results. As swelling of the wound occurs, the wires should be loosened to prevent strangulation of the tissues. Small-caliber wire was found to be entirely unsuitable as it quickly cut through the tissues, loosened and acted only as a foreign body. It is probably a wise precaution to drain all except the completely clean intra-abdominal wounds, not for present infection but to prevent future trouble. As a result of underlying infection the abdominal wall gains tensile strength more slowly than normal. It was found that wire stay sutures should ordinarily remain in place 15 to 20 days. Early removal of the wires, even in wounds that appeared strong, was followed by evisceration sufficiently often to warrant the adoption of this view.

Bile peritonitis developed in several patients with liver wounds, in whom the abdominal wall had been tightly closed with no provision for bile drainage. There is extensive seepage of bile following a liver wound and the abdomen should be routinely drained through a laterally placed stab wound to allow escape of bile and minimize peritonitis.

Extensive intra-abdominal abscesses, peritonitis and fecal fistulae resulted from the breakdown of colon wounds which had been repaired

and dropped back into the abdomen. While a wound may occasionally heal without complications the majority of patients will develop abscesses, fistulae, peritonitis and die unless the injured segment of colon is exteriorized by subsequent surgery. Injured segments of colon must be exteriorized or functionally excluded by a proximal diverting colostomy. All but the extreme lower portion of the colon can be mobilized and brought to the surface. Wounds involving the lower sigmoid or rectum should be repaired and defunctioning colostomy performed proximally. In exteriorizing an injured segment of colon the bowel should be brought out through a laterally placed muscle-splitting incision and not through the primary operative incision. The colon must be mobilized sufficiently to allow it to lie in the wound without tension, otherwise the exteriorized segment will retract into the abdomen with infection of the wound and formation of intra-abdominal abscesses.

Small bowel fistulae were more prone to develop at the site of a repaired perforation than through an anastomosis. This is probably due to a wider zone of tissue destruction about the perforation than is evident at the time of repair. Patients with small bowel fistulae were frequently severely dehydrated and appeared moribund on admission. Procrastination beyond the time necessary to restore fluid and improve electrolyte balance is not justified. Regardless of the degree of infection present in the abdomen and abdominal wound these patients should be operated upon as early as possible to close the intestinal fistula. The patient may appear too critically ill to withstand abdominal exploration and one may be tempted to delay operation for several days in the hope that the patient's condition will improve; however, this is usually futile wishful thinking; delay in operation to close the fistula will result in gradual decline of the patient and his death.

Round worms were the cause of intestinal fistulae in several instances. The ascaris is an inquisitive worm, constantly probing about, and will work itself through a freshly sutured perforation or anastomosis. This complication was seen in six patients and ascarids were found lying free in the abdominal cavity. Since certain United Nations troops were found to harbor ascaris routinely, such a patient with a small bowel fistula was treated to rid him of round worms before any attempt was made to close the fistula. In two cases in which preoperative vermifuge was omitted, round worms again worked themselves through the anastomosis and out through the abdominal incision.

Duodenal wounds which had been repaired at the initial surgery frequently broke down with the development of duodenal fistula. This is a grave complication and the course of these patients is rapidly

downhill because of loss of bile, fluids, electrolytes and digestion of the skin. If the patient is to survive, provisions must be made for the maintenance of his nutrition and replacement of fluids and electrolytes. Nine patients who had duodenal fistulae secondary to the breakdown of the duodenal wound were operated upon and the duodenum closed and jejunostomy performed for feeding. Wounds involving the posterior aspect of the duodenum buttressed against the posterior abdominal wall were found to heal better than wounds located on the anterior free surface of the duodenum.

Closure of duodenal fistulae at a second operation was not usually successful and the duodenal fistula frequently recurred after 3 to 5 days. Sump drainage was employed in these cases and all bile and duodenal contents were collected and returned to the intestinal tract through the jejunostomy. The use of a Levin tube in the stomach and duodenum is of value in preventing pressure on the repaired duodenum and may assist in preventing breakdown of the repair. Two patients with right kidney injury requiring nephrectomy were found to have, in addition, wounds involving the posterior aspect of the duodenum. In wounds about the right kidney the duodenum should be routinely explored for injury. Patients with duodenal injuries must be considered absolutely nontransportable until the outcome of the repair is determined.

Biliary fistulae developed in a few patients in whom a perforating wound of the gallbladder had been repaired at the initial surgery with no provision for drainage of the gallbladder. Perforating wounds of the gallbladder are preferably managed by cholecystectomy and if for some reason this procedure is not possible, a cholecystostomy should be performed following the repair of the perforating wounds.

Wounds of the spleen should not be repaired. Two patients developed delayed hemorrhage from lacerated spleens which had been repaired and required subsequent splenectomy. The pulpy consistency of the spleen is such that repair of this friable organ is an unsatisfactory procedure. Suturing of the splenic tissue has been compared to "suturing a wet paper bag full of raspberry jam." Wounds of the spleen require splenectomy.

Intestinal obstruction occasionally developed as a result of herniation of a knuckle of intestine into the wound of entry or exit in the abdominal wall. This problem can be prevented by closing the wound of entry or exit at the initial surgery or if utilized for a drain site, the size of the opening should be reduced to prevent herniation of the bowel.

Spreading retroperitoneal clostridial cellulitis was present in a few cases with perforating wounds of the rectum. To prevent this serious complication a proximal defunctioning colostomy must be performed

and the perirectal space widely drained from below at the initial surgery. Rectal injuries almost never occurred alone and were usually associated with fractures of the pelvis, hip, wounds of the bladder and small intestine. Rectal injuries are among the most serious of war wounds and carry a high mortality because of the severity of the injury and infection. Every effort must be made at the initial surgery to prevent further fecal contamination and to provide open free drainage of the areolar tissue about the rectum.

Suprapubic tubes were occasionally placed too low in the bladder lying against the pubis and produced the painful complication of osteitis pubis. This can be avoided by bringing the suprapubic tube out of the dome of the bladder and away from the pubis. Perivesical infection secondary to perforating wounds of the bladder is a common complication. Repair of the bladder wall and drainage of the space of Retzius should be routine to minimize the effects of perivesical contamination.

The breakthrough of malaria was cause for concern during the early days of the war until the condition was recognized. After wounding, suppressive therapy was occasionally omitted and frequently these patients developed high temperatures, without chills, a few days after arriving at rear area hospitals. These high temperatures were initially thought to be due to some hidden complication or wound infection; however, blood examinations revealed the true cause of the fever and treatment with chloroquine promptly controlled the symptoms. Latent malaria is prone to break through following severe injury.

Circular adhesive tape around the penis to anchor an indwelling urethral catheter produced marked edema with threatening gangrene of the penis in two cases. Indwelling urethral catheters should be anchored in urethra with longitudinal adhesive and never anchored by encircling tape.

Clotted hemothorax requiring decortication developed in a high percentage of patients when the hemothorax had been treated by intercostal tube drainage rather than by multiple needle aspirations. Multiple tappings of the chest are a time-consuming procedure and frequently these patients require two to three aspirations each 24 hours for the first few days. The pressure of work in the forward hospitals occasionally was such that multiple daily aspirations could not be done and closed intercostal tube drainage was employed as a substitute with an underwater seal. While this procedure may possibly be acceptable when the patient is to remain in one hospital, it was found to be an unsatisfactory method when the patient required evacuation. Frequently the patient would arrive on his litter holding the bottle of water upside down on his abdomen with the water churning back and forth into the pleural cavity with each respiration. Oc-

casionally the tubes were so placed in the chest that they did not provide dependent drainage and acted merely as a foreign body.

An occasional patient, who had suffered a severe secondary hemorrhage, was received for evacuation to the Z. I. with gauze packing stuffed into the wound to control bleeding. These patients all had an underlying arterial injury and required further surgery to control the injured vessel before they could be evacuated. No patient who has had a severe secondary hemorrhage should be considered safe for evacuation until the injured vessel has been inspected and repaired or ligated. Packing the wound with gauze or hemostatic agents may temporarily control the hemorrhage but bleeding will recur. Impending hemorrhage can often be forecast by the appearance of the wound. The intermittent discharge of clots or small amounts of bright red blood from an infected wound is a sure indication that there is an underlying vascular injury, and is the warning that a furious secondary hemorrhage is soon to occur. These patients should be considered nontransportable until the vascular lesion has been controlled.

The high incidence of secondary hemorrhage during the early months of the war constituted a serious problem in rear area hospitals. These hemorrhages almost always originated in grossly infected wounds with unknown underlying vascular injury. When the hemorrhage developed within a plaster cast a few patients almost bled to death before the cast could be removed and a tourniquet applied.

When the major artery in an extremity has been ligated, fasciotomy is often necessary to prevent further restriction of blood supply due to postoperative swelling. Intense swelling of the soft tissues within the confining fascial planes may completely compress the remaining blood vessels of the limb with resultant gangrene. In such cases incision of the fascia will relieve the constricting pressure, allow the compressed vessels to dilate, and reestablish the blood supply. Sympathectomy, on the other hand, will accomplish little or nothing since the interference with blood flow is not due to spasm of the vessel but to external compression. Three patients were admitted with cold swollen forearms and hands with early gangrene of the fingers, following ligation of the brachial artery. In each case cervical sympathectomy had been done without benefit. Incision of the confining fascial envelope from above the elbow to the hand was followed by immediate return of circulation in two of these cases. Fasciotomy should be done without hesitation and before gangrene develops when postoperative swelling threatens the blood supply of an extremity.

Clostridial cellulitis and myositis, as seen at Tokyo Army Hospital, usually developed in a poorly débrided wound in which damage to a major artery was present. Extensive incision and drainage and ex-

cision of necrotic tissue followed by the use of an oxidizing agent such as hydrogen peroxide or zinc perioxide combined with large doses of antibiotics gave uniformly good results with clostridial cellulitis. Therapeutic gas antitoxin appeared to be of little value. Amputation was performed only in those cases in which the extremity was obviously gangrenous. The incidence of clostridial infection can be reduced by thorough initial débridement.

Neurosurgical injuries presented a serious problem in the early months of the war because of lack of skilled neurosurgeons. This problem was resolved by organization of neurosurgical teams which were assigned to forward hospitals in Korea, making available skilled neurosurgical treatment in a matter of a few hours. The prevention of pressure sores in paraplegic patients in the early phases of the war constituted a major nursing problem. Stryker frames were obtained which greatly facilitated the care of these patients and eliminated the pressure sore problem. Turning frames were subsequently used in air evacuation of paraplegic patients from Japan to the United States allowing continuous care en route.

Renal insufficiency, with varying degrees of a uremic state presented a problem in many of the more seriously wounded patients. The incidence of this disorder did not vary appreciably throughout the war.

Serum hepatitis was frequently seen in patients who had received large numbers of blood or plasma transfusions. The use of plasma was discontinued because of the high incidence of hepatitis following its administration.

Frostbite cases were seen in large numbers during the first winter of the war and constituted a serious problem. Frozen extremities will frequently appear black, shriveled and mummified with the appearance of dry gangrene; however, this appearance should not be the basis for immediate amputation. In many cases the black, shriveled skin will slip off in 3 to 4 weeks revealing an intact, viable part. Amputation of frozen parts can be delayed indefinitely unless the part becomes moist and infected, producing generalized symptoms. Frostbites should be gently cleansed and exposed to the air. No dressings should be applied. In cases where Vaseline gauze dressing had been applied to frozen parts, infected moist gangrene developed, necessitating amputation in some cases.

A strong tendency was noted in the rear area hospitals to use split-thickness skin graft to cover defects which could be closed primarily by mobilization of the skin or by rotating flap. Because of the retraction of the skin, skin defects often appear much larger than they actually are. Since the quality of split-thickness skin graft is very

inferior to normal skin covering, grafts should be reserved for those cases which cannot be closed otherwise.

A number of small arteriovenous fistulae in the extremities were overlooked in the early months of the war. Almost without exception these small A–V fistulae developed in patients who had sustained hundreds of small, minor, penetrating wounds of an extremity. The A–V fistulae usually became evident in 4 to 6 weeks after injury and frequently after the patient had been restored to duty. Any patient who has sustained multiple small penetrating wounds of the extremity should be carefully checked approximately 1 month after injury for evidence of A–V fistulae.

Other problems of the early phase of the war were related to scanty records, language barrier and evacuation of patients. Scanty records often failed to provide a clear concept of the extent of the injury and treatment. The early lack of interpreters and language difficulties with many of the United Nations soldiers created a problem in communication and deprived the patient and the doctor of the advantages of a thorough history. The assignment of interpreters overcame this problem for rear area hospitals. Too early evacuation of some of the more seriously injured patients and other problems of evacuation were solved as the war became more stabilized and medical personnel better indoctrinated.

Several approaches were employed in a continuing effort to improve the standard of medical care and to reduce complications to a minimum. Photographs were made showing typical complications which resulted from violation or omission of some principle at the initial surgery. These photographs were hand-carried by the surgical consultant on his regular visits to Korea and discussed at each medical installation to emphasize the principle involved and to dispel any faulty preformed ideas of wound management. The "followup" card was widely used to enable each doctor to follow the course of his patient to determine the final outcome of the case. An intensive 1-day indoctrination program for newly arrived doctors was conducted at Tokyo Army Hospital, designed to acquaint the new officer with the medical situation in the Far East Command. The principles involved in the care of battle casualties were reviewed and typical patients were demonstrated to further emphasize the soundness of each principle. When possible, the policy of orienting newly assigned doctors in rear area hospitals for a few weeks before assigning them to forward units was profitable and assisted in the standardization of medical care. It is felt that an atlas of war surgery depicting typical wounds and their management would be of great value in the library of each hospital, especially during the early phases of a war, and would visually emphasize guiding principles more clearly than the written word alone.

RECENT ADVANCES IN MEDICINE AND SURGERY

The impressive reduction of mortality in the Korean war is evidence of the high quality of medical care provided. It is hoped that even higher standards of military medical practice will result from the continuous striving to improve.

SPECIFIC CONSIDERATIONS IN PRIMARY SURGERY OF THE EXTREMITIES*

COLONEL JOHN M. SALYER, MC
CAPTAIN JOHN O. ESSLINGER, MC

Fifty-six percent of the last 7,200 United Nations troops injured during the Korean war sustained wounds of extremities. This percentage, which all will agree is quite considerable, is somewhat lower than was anticipated in view of past statistics on the anatomical location of war wounds and by virtue of the fact that a significant number of those wounded were wearing protective nylon vests which have so often afforded protection to the extent that potential death-dealing missiles have been deflected by or retarded in the nylon armor plates, thus often sparing the upper abdomen and chest of any injury or permitting relatively minor wounds beneath the protective vest. Nevertheless, a paradox has arisen in that the incidence of extremity wounds has not increased over those percentages determined prior to the present armor designed to offer such encouraging and proven protection to the upper torso.

It would seem reasonable to assume that other body areas, apart from the head and chest, will be provided with protective devices in future wars. It is predicted, although to my knowledge no official overtures have been forthcoming, that the next anatomical areas to be given armor coverage will be the lower half of the lower extremities. Surgeons trained and experienced in the field of traumatism, not to mention orthopedists who are even more aware of the danger to this area, view with grave concern and consternation the surgical and therapeutic problems imposed when open fractures of the lower third of the tibia and fibula are encountered. The relatively poor blood supply and paucity of soft tissues for subsequent bone and tendon coverage are deterrent factors which spell out an ominous warning that occasional serious complications may be expected and the final functional results may not always be ideal.

With such traumatic problems the nonambulatory phase, as well as total periods of hospitalization, will of necessity be prolonged, although such unfortunate patients are given the most detailed and

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expert surgical and orthopedic care at an early hour and under the best of professional circumstances. Unduly delayed and/or inadequate débridement of such wounds that confronts the military surgeon during periods of military conflict may result in significant infections that may require an amputation or even cost the patient his life. Credit is given to rapid methods of evacuation, in most instances detailed and meticulous débridements by competent surgeons, whole blood in adequate quantities, specific and broad-spectrum antibiotics, and a stringent policy regarding the proper application of, and the early splitting of, plaster casts and all underlying circular dressings down to skin level.

The remainder of this discussion will deal with the forward surgical care of extremity wounds—the initial phase in the divisional area; this includes care forward to and at first priority hospitals (Surgical Hospitals, Mobile—so called during Korean war). Not all, but most surgeons who have had experience in the evaluation and surgical care of war wounds will agree that the professional care given forward to the mobile surgical and evacuation hospitals, i. e., in the battalion aid stations, collecting companies and clearing stations, should provide wound care essentially as follows: Control hemorrhage; apply temporary splints and first aid dressings; evaluate the patient as a whole, as well as specific injuries—wound shock being foremost in mind; clear and maintain airway; provide adequate initial shock therapy; control apprehension and pain with barbiturates and narcotics—if wound shock is evident or impending, narcotics are given intravenously and in small doses; administer tetanus toxoid; institute antibiotic therapy; render transportable; triage as to type of selective evacuation; and, last but not least in importance, make initial entries in the Field Medical Record—these concise full-coverage entries will be of inestimable value to medical officers providing professional care throughout the chain of evacuation and hospitalizations.

All but the most minor of wounds of the extremities, as well as war wounds elsewhere, should only be given initial definitive surgical care where the following types of personnel and facilities are available:

1. Surgeons well versed and trained in the care of war wounds.
2. Anesthesiologists and anesthetists available in adequate numbers and provided with proper equipment and anesthesia agents.
3. Whole blood provided in ample quantities.
4. Roentgenographic facilities for wound evaluation and localization of radiopaque foreign bodies. A small missile producing an apparent minor wound of the thigh has been found to traverse the thigh, peritoneal cavity and terminate above the leaf of the diaphragm, not to mention other bizarre missile phenomena such as intravascular migration.

5. Ample surgical supplies processed and sterilized as required; suitable dust-protected operating space or rooms, sufficient operating tables, and other essential equipment to perform large numbers of aseptic surgical procedures satisfactorily.

The above minimal requirements are not available in advance of the Mobile Surgical Hospital.

Early First-Aid Splinting of Extremities

The Army half-ring leg splint has been employed with very satisfactory results during the Korean war. We in the Army have had little experience with the "light beaverboard trough-type" splint presently used to some extent by some Navy medical installations. This linear fenestrated splint would appear suitable in most instances but would seem not to be quite as suitable when traction should be employed, which is frequently so necessary. The wooden trough does not appear to be as adaptable for counter-traction apposition to the ischial tuberosity and pelvis as the Keller half-ring splint. Traction "Army style" is effected by applying traction straps over laced shoes. Only rarely has traction been improperly applied or maintained for sufficient periods to produce blisters and superficial areas of necrosis about the foot and ankle. Well-padded wire ladder splints are employed for foot and ankle injuries. Adequate splinting is our primary concern when preparing those with upper extremity fractures for transport to forward hospitals where the first phase of definitive wound care is provided. The arm can be immobilized by bandaging it to the chest with a Velpeau-type dressing. Wire ladder splints are frequently of value for fractures of the upper extremity.

Forward Evacuation

The transport of the wounded to the rear or laterally proved to be very successful during the Korean conflict. Ambulances much improved as to comfort over those employed in World War II were employed around the clock, almost entirely at night, when helicopters were employed only on rare occasions. Helicopter and light plane transport for any and all types of battle injured was successful to an extent that may never again be realized in future conflicts—in Korea the United Nations had air supremacy south of the main line of resistance throughout the entire war. Periodic air raids by the enemy would have made forward air evacuation much less successful as well as very costly in life and aircraft. It is doubtful if any better method or mode of forward evacuation will ever be devised for transport of patients with severely wounded extremities than that afforded by a helicopter ambulance.

RECENT ADVANCES IN MEDICINE AND SURGERY

Early Care of Extremity Wounds

Simple and Mixed Soft Tissue Injuries

This implies surgical débridement and complete hemostasis without any attempt at primary wound closure. After careful evaluation of the extremity for possible artery, nerve and bone damage, the extremity is shaved, prepared and draped in accordance with good current operating principles. Compromise or deviation from such technics should never be condoned. As a general rule, extremity wounds are extended by adequate longitudinal incisions. Oblique or transverse incisions are only employed on flexion surfaces overlying joints. Only a small amount of skin beyond the primary wound should be removed, as it is vascular, resistant to infection, and should be retained to facilitate delayed primary closure a few days hence.

Devitalized fascia and muscle are excised as completely as can be determined after the deep fascia is incised even beyond the limits of the skin incisions. Metallic foreign bodies are removed as encountered but extensive exploratory probing and dissection for purposes of removal of small metallic bodies is not warranted. Other foreign matter, such as soil, gravel, bits of clothing, boot leather and splinters, is carefully removed with all devitalized tissues. Inadequate surgical care of significant extremity wounds such as not conforming to the above-mentioned concepts of surgical care will result in a wound pabulum most ideal for the growth of virulent bacteria and almost 100 percent of troublesome wound infections. However, a very low percentage of wound sepsis, none of which is likely to be threatening to life or limb, can be anticipated when such extremity wounds are provided early care by surgeons well indoctrinated in the care of wounds produced by war missiles and other types of destructive forces, be they explosive in nature or inflicted by odd forces of nature. Instillation of antibiotics and chemotherapeutic agents into extremity wounds is almost never recommended.

Mixed Soft Tissue, Joint, Nerve and Vessel Wounds

In addition to the débridement steps listed above, the following specific surgical measures are recommended:

Joint Wounds. Massive injury near and involving joints presents distinct surgical problems which deserve comment. The joint is irrigated with sterile saline solution; foreign matter and devitalized tissue such as detached cartilage and bone are removed. The synovial membrane and/or joint capsule should be closed if possible with absorbable suture material and the remainder of the wound left open. Antibiotics (penicillin and streptomycin) are injected into the joint cavity.

Nerve Wounds. It is obvious that all structures such as nerves and blood vessels are given the most detailed anatomical consideration during any type of surgical procedures on extremities. A careful and detailed clinical record is made of the nerve injured or severed and the exact level or site of injury is accurately recorded. Early primary suture of major nerves is never attempted; neither is it necessary to mark the ends of nerves as they are readily found at the time of delayed repair by exposing their proximal and distal portions beyond the confines of the original wound and tracing them to the site of injury.

Major Vessel Wounds. This important and interesting problem will be discussed in detail at this meeting by military surgeons who have made immeasurably valuable contributions in this field during the Korean war. It can be stated that when ligation of a severed artery is not indicated, early establishment of the major arterial blood flow to the distal portion of the extremity is attempted as soon as the débridement is completed. End-to-end anastamosis is desired and considered ideal if feasible. Autogenous vein grafts and homologous arterial grafts have likewise given very encouraging results. The site of repair or vascular graft should be covered with viable muscle or subcutaneous tissue and the remainder of the wound left open.

Wound Dressing. One layer of fine-mesh dry gauze is employed to cover the entire raw surface of the débrided wound. Fluffed coarse-mesh gauze is loosely placed to fill in and extend well above the level of the wound defect. Circular bandages are so arranged that tourniquet-like constriction will not result.

Hand Wounds. Early in the Korean conflict, hand wounds were closed primarily if remaining tissues permitted. This method of management resulted in an infection rate of approximately 90 percent of such wounds. Two years before the end of the war, it was deemed advisable to advocate a nonclosure policy which gave much more encouraging results. Débridement should be performed with the most meticulous care—rash excision of questionably viable important structures and tissue is not advocated. The retention of avulsed skin is highly desirable and it should be loosely tacked down by spaced sutures and immobilized by the wound dressing. Such attached skin will often provide cover for exposed nerves, tendon sheaths, tendons and other hand structures.

Forward Amputations. Under war conditions, the guillotine, or open-type amputation, is the procedure of choice as well as the method that has given the most satisfactory results. It was indorsed throughout the Korean conflict. The guillotine, or open, amputation implies a total débridement of an extremity hopelessly destroyed by trauma

or infection or both. Even today it is often a lifesaving procedure regardless of the etiological trauma producing a mangled extremity. It has been common surgical knowledge since World War I that the end of the amputation stump must be left open in order to control infection, just the same as following the débridement of any war wound of an extremity. As ideal as antibiotics are, they have not provided sufficient bacteriostasis to cause military surgeons to alter this policy.

Technic. A tourniquet is always used. The amputation is done at the lowest possible level consistent with the total removal of devitalized tissue and without regard to so-called elective sites of operations. Reamputation or revision of the stump is always necessary. Such revisions can be performed in the Zone of Communications or Zone of Interior where surgery can be accomplished under ideal conditions. The skin incision may be roughly circular or oblique. The subcutaneous tissue and deep fascia are cut at the level of the retracted skin. Proximal retraction allows the muscle to be severed at a slightly higher level. All structures are again retracted and the bone is sawed without stripping the periosteum. If the lower leg is being amputated, the fibula is amputated about 1¼ to 1½ inches above the stump of the tibia. All major vessels are ligated and the tourniquet removed, after which complete hemostasis is accomplished. The nerve is pulled down, divided and allowed to retract into the stump. Sterile stockinette is fashioned over much of the remaining extremity and fixed by means of skin glue. Minimal gauze dressing is applied to the raw stump surface, and sufficient traction is maintained to cause the stump end to appear as an inverted cone, the bone being at the apex. Constant elastic traction is maintained from the end of extension splint bars incorporated in a well padded plaster cast fashioned to allow the very necessary and only safe method of bony prominence counter-traction. Injudicious counter-traction applied to the soft tissues above the amputated stump will almost always result in an impairment of the normal venous return and subsequent arterial insufficiency.

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DISCUSSION

COLONEL AUGUST W. SPITTLER, MC

My observations on primary surgery as far as the Korean conflict is concerned were made on the casualties as they arrived at Walter Reed Army Hospital.

I do not disagree in general with any of the premises that Colonel Salyer and Captain Esslinger brought out but will elaborate a little on them. As far as the wounds in general are concerned, I cannot emphasize too much the importance of a thorough initial débridement. When an adequate débridement was done, a secondary closure was not as imperative at an early date as is often talked about. Although a closure on the fifth day or soon thereafter gives an ideal result, judgment on those closures must be good, as a closure of an infected wound is worse than not closing. When the débridement had been inadequate, closed or not closed, infection had spread up and down fascial planes. The patients, although afebrile (due to antibiotics) were weak, pale and anemic. Several severe hemorrhages occurred in them on removal of dressings.

Although extremity surgery seems simple, it is a source of our greatest morbidity and, in many cases, a preventable one if débridement is well carried out to include all devitalized tissue, entire muscle bellies that are deprived of blood supply if necessary, and foreign bodies. To sacrifice bone whether attached or detached is not necessary and makes reconstruction difficult. Bone chips are not dead tissue—they usually survive if given a clean bed to lie in, or at least provide a lattice work for new bone formation.

In the phased treatment of fractures, traction on a badly mangled extremity is not as important as actually holding the leg in alignment as there is little muscle spasm.

Either the half-ring splint or the plywood board splint is effective for initial phase. After débridement, plaster is still best. We have worked for some time in producing a lighter type of plaster using a resin mixture in the solution. Unfortunately, no casts made of this material were ever on our patients from Korea, although some was sent to Japan for that use. It is now available mixed in the bandage so that only water and catalyst need be added.

Remember, an arm only directs the hand. Position of the hand is important and it should be placed in a position of function.

In the leg—overpull is to be avoided. A slight shortening produces healing more rapidly.

Joint Injuries

Early débridement is essential with closure of capsule. I have seen some joint-injured patients arrive at Walter Reed Army Hospital, however, with synovial drainage from wound and no limitation in joint motion. Spontaneous closure occurred in a few weeks.

The Hand

There is no difference in the initial surgery of the hand from that of any other part.

Try not to sacrifice skin. You may need to tack it down. Do not make a tight closure.

Consider—filleting a useless finger to get soft parts to cover rest of hand. Try to cover tendon with soft parts.

Do not immobilize too long. Early function is important.

Cover with skin as soon as clean wound is assured. Skin from an abdominal flap or a split-thickness graft may be used at times.

More hands are ruined by complete prolonged immobilization than by early mobilization.

Amputation

Open amputation—so-called guillotine—is and will be the operation of choice for traumatized extremities.

Long skin flaps are not necessary if traction is applied and maintained. Long skin flaps may be retained to cover the condyles of the knee.

Dressing a guillotined stump with the changeable dressings outside of the stockinette is advocated.

Traction must be continuous until end of bone is covered.

A guillotine stump is easily converted and is often ready for fitting as soon as an originally closed one, as during the traction stage the adherence of muscles to the end of bone and the shrinkage desired is accomplished.

Four amputations which are now advocated by us are to be thought of in considering a primary amputation of any extremity:

1. Syme—or modified ankle disarticulation.
2. Knee disarticulation.
3. Elbow disarticulation.
4. Wrist disarticulation.

An open disarticulation can be done as easily as an above-the-joint open operation; it is now to be preferred.

In the ankle every effort should be made to save the heel pad as advocated in the first stage of our staged Syme amputation.

Internal Fixation

In the seriously comminuted fractures primary internal fixation is not to be considered. Early medullary nailing in communications zone hospitals in selected cases must be considered for evacuation as well as early return to duty, particularly if the initial débridement was good and effective in securing a clean wound.

Bone

No replacement is yet available as good as bone. Banked bone should still be considered for early use. Particularly the types that can be kept sterile at room temperature should be considered for early implantation even if for later reconstruction only. Bone is a living tissue.

Pearl Harbor experience—7 December 1941, Tripler Hospital where I was Chief of Surgery.

Problem. Triage—All wanted to be this officer.
Personalities—All wanted only to specialize.
Shock wards were life savers although Honolulu's blood bank was most effective adjunct.
Every doctor wanted to suture wounds. All had to be opened later.
Sulfa drugs were effective.
Records were poor—suggested personnel for this only.
Identity of patients was hard to keep when stripped and unconscious and/or later died.
Tape or wire recording of records now thought excellent method.

SPECIFIC CONSIDERATIONS IN PRIMARY SURGERY OF NERVOUS SYSTEM*

LIEUTENANT COLONEL GEORGE J. HAYES, MC

Basic Principles

The Korean war has demonstrated again that which needs no further demonstration. There is no substitute for prompt, definitive treatment of missile wounds. This is true of wounds of the nervous system. Early in the war treatment was delayed, and débridement was inadequate or not definitive. Infection with consequent morbidity and morality was common. With the advent of neurosurgical teams within the zone of operations these complications fell to the level generally existing at the close of World War II.

I do not intend to discuss the minutiae of neurosurgical technic. Nor will we cover the care of peripheral nerve injuries, for beyond proper notation of the fact that such injury exists there is no specific treatment indicated at the time of wounding.

Patients having wounds of the brain do not usually present a problem on preoperative blood volume replacement. If associated injuries cause a need for blood this should be administered as indicated without regard to the presence of brain damage. The patient in deep coma may well receive benefit from a tracheotomy if tracheobronchial respiratory embarrassment arises, that is usually sufficient indication that one should be performed. With or without a tracheotomy the unconscious patient should be maintained in the "coma position." This is a lateral recumbent position with the ventral aspect of the head and body inclined slightly toward the supporting surface. Vomitus, mucus and blood will tend to run from the mouth instead of being aspirated and thus pneumonia, lung abscess or drowning is prevented.

X-rays of the skull are essential aids in planning the surgical attack. These give information regarding the size, number and position of bone fragments within the brain. The path, position, size and, to some extent, the effects of the missile may be ascertained. General anesthesia with an endotracheal tube should be smoothly and quickly admin-

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istered. If the aid of a skillful anesthetist is not available it is better to use local anesthesia as the straining which occurs in a stormy induction may cause further damage or even death.

The operation on the wounded brain is essentially a débridement which also includes scalp, skull and dura. Great care must be taken to remove all bone fragments, hair, blood and nonviable brain. The removal of the missile is not always essential and is generally contraindicated if to do so would impose a new neurological deficit.

The use of lighted retractors and other instruments is generally advocated in the search for foreign bodies and bone fragments. Personally, I found that palpation with the index finger was advantageous and resulted in more thorough identification and removal, with less operative trauma.

The skull is a rigid box containing substances which are of relatively similar density. The shock effects of a missile may cause laceration of the brain or its vessels distant to the point of impact, and the possibility of such an occurrence must always be kept in mind.

The exposed brain is easily contaminated by bacteria. Its response is to swell and extrude out of the cranial defect. This impedes venous return from the affected area, which causes further swelling. A cyclic phenomenon is thus set up which may lead to death or massive tissue destruction. Therefore, a major departure from the usual débridement concept is forced upon us by the nature of the tissue and its reaction to trauma and infection. Following débridement, the brain is covered and protected by primary wound closure. Fortunately the scalp is highly vascular and, if properly trimmed to the level of viable tissue, will readily heal.

The dura must be closed to prevent scar formations between scalp and brain and to defeat bacterial invasion. Often a graft is needed. This may be obtained from the adjacent periosteum, galea or muscle fascia.

The routine use of fascia lata has been advocated as a dural graft source. A comparison between cases so treated and those in which dural repair was accomplished with galea, etc., showed that a significant increase of wound disruptions resulted when fascia lata was used.

Postoperatively the coma position with frequent changes from side to side should be maintained if indicated. Fluid and electrolyte administration is essential, and the "dehydration treatment" has no place in the care of these men. If coma continues, tube feeding with a high-protein and high-caloric formula simplifies the maintenance of metabolism.

Patients who have injuries to the spine and spinal cord require specific care as soon as they are first seen. A normal anatomical posi-

tion is generally best for transportation, face down if at all possible. Jostling and jouncing are to be avoided. A catheter should be inserted in the bladder and the indicated blood and fluids administered. Combined wounds are common in this group and transportation to a neurosurgical team or surgery directed toward the spinal cord are both subordinate to lifesaving surgery for the associated wounds which are usually of the abdomen or chest. Alternate face-down and face-up positioning must be started within a few hours after wounding to prevent formation of decubiti. This can be accomplished by sandwiching the patient between prepared litters or by use of the Stryker frame. The latter has proved practical as a piece of forward equipment and as a means of transportation via air, water or land. It also requires fewer people to manipulate than the improvised arrangements.

Débridement is carried out thoroughly and extensive decompression of the cord performed. The dura is closed or left open as circumstances dictate. Here again, primary wound closure is performed if the wound path is included in the laminectomy incision. If the wound is not in this incision, it is secondarily closed in 5 days.

Continuous bladder drainage is provided via an urethral catheter. At the forward level, no attempt is made to institute tidal drainage, and suprapubic cystostomy is done only when bladder wounding forces this step.

Penicillin and streptomycin are administered routinely in both brain and spinal cord injuries. Crystalline penicillin is used intravenously preoperatively and immediately postoperatively. Other antibiotics are used if indicated but *none* are applied directly to the wound area.

Neurosurgical Teams

We have sketched out the basic principles involved in the primary surgical care of war wounds of the brain and spinal cord. Equally important and requiring much planning are the aspects of patient transportation, location of a neurosurgical team, composition of the team, its organic equipment and the amount of surgery such a unit can be expected to accomplish.

Patient transportation will be discussed in detail by another speaker. However, the avoidance of aggravating the wound by trauma because of rough handling should be stressed. Helicopter ambulance service is preferable when the tactical situation permits. Postoperatively, the patients should be moved, by air if possible, to a base zone center as soon as their condition permits movement. The forward unit cannot afford to become overloaded with long-term cases.

The forward unit providing primary definitive neurosurgical care needs to be within at least 12 hours evacuation time from the source of patients. A longer time will be reflected by an increased number of infections and a higher mortality rate.

The hospital to which a neurosurgical team is attached should be of the evacuation type, for this is large enough to absorb the postoperative care of the patients, to aid in the preparation of sterile supplies, and accommodate the team itself without undue strain. This may not be practical and the team will have to be placed with a MASH or other unit. In any event, to ever consider making these neurosurgical units self-sustaining, miniature hospitals, is to invite waste of manpower and equipment.

A suggested team is as follows:

2 Neurosurgeons (both high *C*).
2 Surgical Nurses.
8 Corpsmen (Surgical Technicians).
1 Anesthetist *C*.

Such a team attached to a hospital will be able to do about 12 procedures per day under optimum conditions for a period of several days. With the exception of special equipment, most of the necessary medical supplies can be drawn from the hospital to which the unit is attached. The neurosurgical group should not be considered a permanent attachment to a hospital but rather a mobile specialty unit. To aid in this function, sufficient organic transportation should be provided for equipment, housing and personnel. Shuttle movements are not practicable.

The number of teams to assign to a Corps or Army area will have to be arrived at by estimating the expected or observed number of casualties. Approximately 10 percent of the seriously wounded men have damage of the brain or spinal cord. Teams, or parts of teams, may have to be moved as needed to cover busy areas.

Ideally, these units should be organized and ready to move at all times, prior to the onset of hostilities. Realistic peacetime maneuvers should be carried out so that the unit members will become efficient in their functions. Our neurosurgeons must be trained to operate with simplicity and speed and have the opportunity to guide their teams in their proposed duties. We do not shirk residency training to accomplish peacetime surgical competence. We cannot afford to be delinquent in such training to prepare for the surgical treatment of war wounds.

THURSDAY AFTERNOON SESSION

22 April 1954

MODERATOR

COLONEL JOHN M. SALYER, MC

AN ANALYSIS OF 2,811 CHEST CASUALTIES OF THE KOREAN CONFLICT*

MAJOR A. R. VALLE, MC

In this paper we present an anlaysis of the 2,811 chest casualties of the Korean conflict who were treated at Tokyo Army Hospital between the beginning of the war and March 1953. A previous report covering 1,535 of these casualties has been published (*21*). However, this paper adds more than 1,000 cases and contains data which were not available at the time of the previous reports. Some conclusions are reported because additional experiences only served to bear out their validity.

Tokyo Army Hosiptal was the center for treatment of thoracic casualties. Approximately 85 percent of our patients were United States military personnel and 15 percent were members of forces contributed to the Korean effort by other United Nations.

During the first few months of the conflict, definitive treatment could not be administered overseas because casualties could be hospitalized in the theater only 30 days. However, as the bed capacity increased, the period of hospitalization was increased to 120 days, making definitive treatment possible.

In this series we have included only those patients who suffered injuries to the intrathoracic viscera and do not include those with only superficial wounds of the chest. Of these wounds, 1,968 or 70 percent were of the penetrating type, 787 or 28 percent were of the perforating type and 56 or 2 percent were results of crushing injuries.

Hemothorax

The most frequent complication of intrathoracic wounds is hemothorax with or without associated pneumothorax. This intrapleural blood may remain fluid or may coagulate and begin to organize. In this series 1,744 patients or 62 percent either had hemothoraces on admission or developed them within the first 2 weeks after admission. Of this number 74 percent or 1,291 remained sterile and 26 percent or 453 became infected.

*Presented 8 December 1953, to the Military Medicine Refresher Course, and 22 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

We treated hemothorax by simple thoracentesis without air replacement. Following removal of the fluid, 300,000 units of crystalline penicillin and 1 gram of streptomycin were instilled. The procedure is repeated every 24 hours, or more often if thought indicated, until no fluid can be obtained and the chest appears normal to physical and x-ray examinations. Specimens of the fluid removed were sent to the laboratory for culture, antibiotic sensitivity tests and other studies as indicated. If infection was present, the antibiotic of choice was administered systemically and intrapleurally, depending upon the manner in which the drug could be administered. Penicillin, streptomycin, terramycin, aureomycin and chloromycetin were utilized.

Eighty percent or 1,395 patients completely recovered after being treated by thoracenteses and antibiotics only. Sixty-eight percent were returned to duty and the remainder were evacuated to the Zone of Interior because of other wounds although they were recovered as far as their chests were concerned.

Many patients had clotted hemothoraces on admission to the hospital or within 2 days of being wounded. From a review of those patients' records, it would seem that the hemothorax clotted within a few hours of wounding, because at no time was any fluid obtained by aspiration. In other patients the hemothorax coagulated gradully, taking from 3 to 4 days to 2 weeks.

Decortication is the established method of treatment for those patients with significant clotted or organized hemothoraces (*3–5*, *7–13*, *15*, *16*, *19*). A total of 254 decortications were performed on patients with both infected and noninfected organized hemothoraces. Of these 76 percent were infected and 24 percent were noninfected. Ninety-one percent were considered as having good results, 4 percent as having fair results and 5 percent as having poor results.

It is noteworthy that 92 percent of the patients who needed decortication had closed intercostal drainage tubes inserted in Korea (*23*). We feel that closed intercostal drainage has many disadvantages as an early treatment for hemothorax. It increases the hazards of evacuation since the tubes were often found improperly clamped off and fluid from the bottles was sucked back into the chest. Furthermore, in hemothorax, closed drainage usually loses its value within 24 to 36 hours because of occlusion of the tube by fibrin and clots and by pleural adhesions about the intrathoracic portion of the tube (*21–23*).

After performing decortications at intervals of 1 to 8 weeks following injury, it was decided that the optimum time for such operation is within 3 to 5 weeks of injury. From a review of the reports published by surgeons who had experience in treating chest casualties during World War II, it would seem that there is general agreement

upon this interval (*10–12*). In those operations performed early, the bleeding was much more severe, there was more edema and foreign bodies, if present, were more difficult to locate.

In 18 cases we used streptokinase and streptodornase according to the procedure described by Tillett and Sherry (*14–18*). We obtained such poor results that their use was discontinued.

Foreign Bodies

It was the policy at Tokyo Army Hospital to remove only those foreign bodies which exceeded 1.5 cm. in greatest diameter, unless, of course, they were in such a location as to be regarded as dangerous to the patient, unless they caused some pathologic changes within the chest, or produced symptoms. Persistence or development of reaction about the missile indicated the need for exploration and removal (*1, 2*).

Three hundred and twenty-seven patients had retained foreign bodies which necessitated removal. Approximately 85 percent of these were shell fragments which varied in size from 1 to 9 cm. in diameter and the remaining 15 percent were bullets of various caliber. The incidence of infection when the foreign body was shell fragment was high, from 60 to 70 percent. When the foreign body was a bullet, the incidence of infection was about 10 percent.

Among the 327 patients operated upon at Tokyo Army Hospital solely for the removal of foreign bodies, the postoperative empyema incidence was only 2 percent. The majority of these patients returned to duty but a small number had to be returned to Zone of Interior because of other wounds.

We found that delaying operation for removal of foreign bodies for 2 to 3 weeks, if possible, decreases the amount of bleeding at operation and makes location of the foreign body easier. Also the patient is usually in much better condition to tolerate the thoracotomy procedure. In reviewing the records, we also found that the empyema incidence among some 150 patients who were operated upon in forward areas for removal of foreign bodies was 25 percent.

Mediastinal Injuries

One hundred and seventeen or slightly more than 4.2 percent of our patients suffered mediastinal wounds. The majority of these patients also had retained metallic foreign bodies. Approximately 65 percent of these patients developed infections which were drained through the pleural space.

We removed 32 foreign bodies from the mediastinum, 10 from the pericardium, and 16 from the myocardium. Three patients had

foreign bodies in the intraventricular septum which we did not remove.

Forty-two patients developed pericardial effusions which were treated with pericardiocenteses and antibiotics. Pyogenic organisms were obtained from culture of the aspirated fluid in about 40 percent of the cases.

The following table shows the extent to which other structures in the mediastinum were injured.

Esophagus	9
Aorta	8
Thoracic duct	5
Vena cava	3
Trachea	5

The majority of these patients, with the exception of those with injuries to the heart and great vessels, were returned to duty in the theater.

Thoraco-abdominal Wounds

It was our experience that many patients with thoraco-abdominal wounds involving the upper abdomen could be handled adequately through the thoracotomy. The exposure is good and it obviates the necessity of an abdominal or thoraco-abdominal incision. It was our impression that those patients who needed extensive abdominal surgery made better progress when separate thoracotomies and laparotomies were done than when a thoraco-abdominal incision was made. Also, infection if it develops, is more localized when separate incisions are made.

Generally those patients who suffered injuries to the diaphragm and spleen in conjunction with their chest wound had these injuries repaired at thoracotomy. We repaired 186 injuries to the diaphragm and performed 8 splenectomies. The majority of these patients were returned to duty in the theater.

Patients with serious liver damage, multiple intestinal perforations with or without resection, colostomies, nephrectomies, etc., were evacuated to the Zone of Interior for definitive chest surgery. If necessary, the temporizing procedure of open drainage with rib resection was carried out so that they could be safely evacuated.

The following list gives the extent to which various abdominal organs were injured:

Liver	201
Spleen	82
Large intestine with colostomy	52
Small intestine	18
Stomach	48
Kidney	33

Approximately 18 percent of our patients suffered wounds involving both the chest and abdomen. Four deaths or slightly more than 25 percent of our mortality were in this group.

Other Injuries

A large number of our patients suffered nerve injuries and/or orthopedic injuries along with their chest wounds. Those patients whose injuries were so serious that there was little likelihood of their returning to duty in the theater usually received only palliative treatment such as thoracentesis or thoracotomy drainage with rib resection and were evacuated to the Zone of Interior.

Bacteriology

Many kinds of bacteria were isolated on culture of the fluid aspirated from the chests of our patients. In the beginning, the infection was usually a mixed one, made up of various gram-negative rods and gram-positive cocci. However, as antibiotic treatment continued, the gram-negative bacilli, such as *E. coli*, *E. freundii*, *Aerobacter aerogenes*, *Pseudomonas aeruginosa*, various Proteus species, etc., were usually destroyed, leaving only the gram-positive cocci to be dealt with.

Hemolytic and nonhemolytic Streptococci were isolated in a number of cases but by far the most common and most persistent organism encountered was hemolytic, salt-resistant, mannite-fomenting (coagulase-positive) Staphylococcus. The Streptococci were easily controlled by antibiotics but usually the Staphylococcus became resistant to all antibiotics except chloromycetin in very high concentrations.

We found various types of proteolytic Clostridia in a number of our cases, which could account for the massive destruction of lung tissue found in these cases.

Morbidity

The prime factor in the treatment of chest casualties is the restoration of normal cardio-respiratory physiology as soon as practicable (*3*, *20*). All such procedures as thoracentesis, decortication, removal of foreign bodies and irreparably damaged lung tissue, repair of the diaphragm and chest wall help restore normal function and decrease morbidity.

We feel that physiotherapy is an important adjunct in decreasing morbidity (*6*). If possible, it is started on the third postoperative day. The patients begin with breathing exercises and blow bottles and passive and active exercise of the shoulder and arm of the side operated upon.

The period of hospitalization, in most instances, varied from 3 to 6 weeks. Following discharge from Tokyo Army Hospital, these patients who were considered candidates to return to duty in the theater were sent to Camp King. This camp was a convalescent and reconditioning center. It was operated under medical supervision and the amount of activity was gradually increased to combat peak. Those patients who could not stand the rigors of combat conditions were weeded out and sent to limited duty.

Approximately 80 percent of the chest casualties who had definitive treatment at Tokyo Army Hospital returned to duty in the theater. Also we know that a considerable number of patients who had to be evacuated eventually returned to duty but we have no data concerning these.

Mortality

It is assumed that the initial mortality in thoracic wounds must be high but we have no overall figures about the mortality of chest wounds in the Korean conflict. However, the delayed mortality appears to be lower than might be expected. Our overall mortality at Tokyo Army Hospital was 0.6 percent and that reported for the Yokasuka Naval Hospital was 1.9 percent (7).

We had 17 deaths in our series of 2,811 cases. Eight of these patients died as a result of serious wounding: 4 patients, of thoraco-abdominal wounds, 1 patient of pulmonary embolism, 1 patient of cardiac tamponade and 2 with serious nerve injuries. Nine of our deaths were due to homologous serum hepatitis. Many other patients, all of whom had received numerous transfusions of plasma and whole blood, developed jaundice but did not succumb.

More than 800 major operations, excluding thoracotomy drainages, were performed without a death, as follows:

Decortications	254
Lobectomies and partial resections	169
Pneumonectomies	5
Splenectomies	8
Thoracotomies for removal of foreign bodies, etc	435

Many factors contributed to this low mortality. We had the benefit of the experience of the chest surgeons in the rather recent World War II; we had more and improved antibiotics; there was plasma and whole blood readily available for transfusion near the battle lines; the Mobile Army Surgical Hospitals could do major surgery if necessary just a few miles from the front lines; evacuation was very rapid. Lastly, but of great importance, the patients were healthy young men with an average age of 23 years.

Late in the war protective vests were introduced which helped decrease the mortality of chest wounds. They are most effective in stopping low-velocity missiles and many soldiers who would have been instantly killed if not protected by the vest, are only wounded.

Conclusions

Our experience with 2,811 chest casualties indicates that, in general, the best early treatment for chest wounds is the most conservative one.

Thoracentesis is the most effective treatment for hemothorax. Approximately 80 percent of the patients with hemothorax were cured by thoracentesis and antibiotic treatment. We feel that closed intercostal drainage is seldom necessary and often dangerous. Ninety-two percent of those patients who required decortication had intercostal drainage tubes inserted in Korea.

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ABDOMINAL AND THORACO-ABDOMINAL WOUNDS*

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Not until the middle of World War I were routine laparotomies performed for exploration of abdominal wounds produced by battle injuries. Wounds of the abdomen were treated by rest and sedation prior to that time. Information was obtained in World War II as to the preferred method of treatment of various types of abdominal injuries. During the final 6 months of the Korean conflict, essentially the same operative procedures were used in all of the forward hospitals.

Incidence

Before the armored vest was used in Korea, 19 percent of the wounds of the body were in the chest, and 11 percent in the abdomen; thus 30 percent of all wounds were in the trunk. There was a decrease of 10 percent in trunk wounds after the use of the armored vest; 8.7 percent of all wounds were in the thorax and 10.8 percent in the abdomen (*1*).

Diagnosis

Patients with intra-abdominal injuries usually arrive at the forward hospital with low blood pressure and a rapid pulse. The time interval from injury to admission, the extent of peritoneal contamination, and the amount of blood loss are factors in determining the degree of injury in casualties with comparable wounds. A rapid response to resuscitation is a good indication that the injury is not extensive. The severely wounded casualty responds slowly to resuscitative measures. Pain is of little diagnostic value because many of the patients have received intravenous morphine prior to admission. Pain is not the most prominent finding even in those patients who have not received morphine.

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In taking the history, it is of value to determine the type of missile which produced the injury and the position of the patient when hit. After penetrating the skin, high-velocity missiles cause extensive destruction of internal organs. Low-velocity missiles of comparable size have a tearing action on the skin, with less internal destruction of tissue; or they may not penetrate the abdominal wall. Inspection of points of entrance and exit of the missile may suggest which organ or organs are damaged.

Abdominal distention is rarely present unless there is massive, intra-abdominal hemorrhage. Boardlike rigidity of the abdomen is seldom seen. When present, it is diagnostic of a perforated abdominal viscus. Patients with chest wounds or superficial abdominal wounds may have marked guarding or rigidity of the abdomen, even though there is no peritoneal irritation. Many patients with perforated abdominal viscus have a soft abdomen at the time of admission. During resuscitation, such patients usually develop rigidity of the abdomen. Generalized tenderness is usually an indication of intra-abdominal injury.

A silent abdomen on auscultation is a good indication of a perforated hollow viscus, resulting in leakage of intestinal contents. If peristalsis is present, along with other negative criteria, intra-abdominal injury is doubtful and the patient should be carefully observed.

Roentgenograms should be taken of all casualties suspected of having abdominal injury. They demonstrate the presence of intra-abdominal shell fragments, free air and retroperitoneal hemorrhage. One is not always able to localize shell fragments by roentgenograms in instances where fragments have entered through the back or lie close to the peritoneum, and where there is a wound of the perineum and buttocks. When a psoas shadow cannot be visualized on a roentgenogram, one should suspect the presence of retroperitoneal hemorrhage.

Peritoneal taps are of little value in establishing the diagnosis of intra-abdominal injury. An abdominal tap with positive findings is a definite aid; while a negative tap does not rule out injury to intra-abdominal organs.

Technics of Abdominal Operations

All patients in this series received pentothal induction and endotracheal gas-oxygen-ether anesthesia, and curare-like drugs. The skin of the abdomen is prepared by shaving, washing with a detergent containing hexochlorophene, and irrigating with saline solution.

Incisions

A long, muscle-splitting incision into the rectus muscle should be used for exploration of the abdomen. It should extend from the costal margin to the pubis. The abdominal incision should never pass through the site of injury; but it should be placed a considerable distance from it or, if necessary, on the opposite side. A systematic examination of the abdominal cavity should be made immediately after the peritoneum has been opened. When bleeding is present, the small intestine should be eviscerated to facilitate rapid exploration of the peritoneal cavity. The bleeding points can then be observed and the hemorrhage controlled immediately. When this has been completed, the contents of the peritoneal cavity should be thoroughly inspected from the cardia of the stomach to the peritoneal reflexion about the sigmoid. When abdominal bleeding is not a problem, a complete examination of the peritoneal cavity should be made without eviscerating the small intestine.

Stomach

On many occasions, battle casualties have eaten a short time before injury. At operation they may still have a full stomach, even though vigorous attempts have been made to empty it. In such instances, it is advisable to incise the stomach and empty it. If this is not done, vomiting, aspiration and acute gastric dilatation may occur postoperatively. All wounds of the stomach require a thorough exploration of the posterior surface. This is accomplished by a transverse incision into the lesser sac through the gastrocolic omentum. The stomach can then be elevated in order that the entire posterior surface may be examined. Wounds of the stomach should be closed by two layers of interrupted silk sutures.

Duodenum

A perforating wound of the anterior surface of the duodenum always requires a thorough exploration of the posterior surface. Adequate exposure is necessary for an accurate repair of these wounds. The ascending colon and the hepatic flexure are mobilized. The duodenum can then be freed from its attachments and rotated medially, thus exposing the posterior surface of the second and third parts. Wounds in the second portion of the duodenum require careful dissection and repair to avoid injury to the common bile duct. It is well recognized that duodenal wounds heal poorly. All wounds should be sutured transversely to prevent a constriction of the lumen. A two-layer closure should always be made, and drains should be placed in the region of repair and brought out through a separate stab wound on the skin.

Liver

A small, superficial laceration of the liver in which there is no bleeding at the time of the operation requires only drainage. Small wounds which are bleeding should be sutured. Large, deep lacerations of the liver should be closed with a hemostatic gauze pack placed in the wound and edges approximated with wide, deep, figure-of-8 absorbable sutures.

Shell fragments are removed if they can be obtained without excessive trauma to the liver. Fragments which are embedded deep within the liver should not be removed.

All liver wounds should be drained, regardless of their size. Large Penrose tissue drains should be brought out through a stab wound in the midaxillary line and placed in each of the following areas. One should be placed in the foramen of Winslow, another anterior to the common bile duct, a third between the posterior surface of the liver and the diaphragm, and a fourth between the anterior surface of the liver and the diaphragm. Patients who are not drained frequently develop bile peritonitis.

Posterior wounds of the liver can be exposed by dividing the triangular and falciform ligaments. This permits the liver to be dropped and the posterior surface may be visualized. Perforation of the diaphragm should be closed with interrupted sutures.

Gallbladder

Wounds of the gallbladder are treated by cholecystectomy. If the gallbladder has been injured, the common bile duct should be carefully examined. If the duct has been injured, it should be approximated over a T-tube. The T-tube should not be brought out through the anastomosis. All injuries of this area should be drained.

Spleen

All injuries of the spleen should be treated by splenectomy.

Small Intestine

The entire small bowel should be inspected from the ligament of Treitz to the cecum. At this time, bleeding points should be ligated. One can determine the type of treatment that is required upon completing the examination of the small intestine. In those instances in which there are only a few perforations of the bowel wall, a closure of the separate wounds should be made. Usually segments of the bowel with multiple perforations will require resection with an end-to-end anastomosis. Wounds of the small intestine should be closed transversely with a single layer of interrupted silk.

Cecum

One of the major problems in abdominal surgery is the treatment of wounds of the cecum. There is little or no agreement on the technic. Ileostomies and cecostomies are contraindicated because it is difficult to maintain electrolyte balance during evacuation. Primary closure of the cecum is frequently unsuccessful.

In small wounds limited to the cecum, tube cecostomies or suturing of the wall of the cecum to the skin are acceptable procedures. If a tube cecostomy is used, it is important to suture the cecum to the anterior peritoneum about the point of exit of the catheter. This will prevent peritoneal contamination, if there is leakage. In larger wounds of the cecum and ascending colon, it is advisable to perform a resection of the cecum with an end-to-end ileotransverse colostomy, or perform a resection of the cecum with end-to-side ileotransverse colostomy and single-barrel colostomy of the proximal colon.

Colon

A colostomy should be performed for all wounds of the colon. A single perforation of the colon should be treated by making a stab wound through the abdominal wall, bringing the injured area of the bowel out, and placing it over a glass rod as a loop colostomy. The wound of the colon is left open and later enlarged. Multiple wounds of the colon are treated by suturing the wound and making a defunctioning colostomy at the site of the proximal wound. In wounds of the descending colon, some surgeons prefer not to mobilize the descending colon but to suture both wounds and perform a proximal defunctioning colostomy in the transverse colon. Defunctioning colostomy should be brought out through two separate stab wounds which are at least 2 inches apart. Multiple perforations with massive destruction of the colon are treated with a resection of the involved segment. The divided ends of the colon are brought out through separate stab wounds at a convenient point.

Pancreas

Pancreatic injuries are rare. Hemorrhage and pancreatitis are the most frequent complications of wounds to the pancreas. All wounds of the pancreas should be drained with large rubber tissue drains placed about the injured area and brought out through a stab wound. The tail of the pancreas should be resected if extensively traumatized.

Retroperitoneal Injuries

Injuries to the retroperitoneal areas frequently cause large hematomas and extensive damage to muscle. The hematomas may be caused by perforation of a large blood vessel. If this occurs, the bleeding

should be controlled and the vessel should be repaired. Ligation of the vena cava, with associated retroperitoneal muscle damage, will frequently cause a secondary hemorrhage. Retroperitoneal muscle injury presents the problems of adequate excision of devitalized muscle and the control of hemorrhage from multiple bleeding points. It is difficult to expose the retroperitoneal muscle in order that an adequate débridement can be performed. When oozing occurs, it is necessary to pack the muscle bed to control the bleeding. This area should always be drained. Postoperative hypotension frequently occurs in patients who have retroperitoneal injuries, but will usually respond to adequate blood replacement. More blood is lost from the damaged muscle than is usually recognized.

Thoraco-abdominal Injuries

The maintenance of adequate oxygen exchange and the relieving of respiratory embarrassment make the chest the first priority in the treatment of thoraco-abdominal wounds. Hemothorax should be treated by thoracentesis and thoracotomies should be performed only on proper indications.

Sucking wounds of the chest should be débrided and closed. The abdomen should always be explored through a separate incision. All perforations of the diaphragm should be closed with interrupted silk sutures.

Abdominal Wall Closure

The peritoneum should be closed with running sutures of chromic catgut. The muscle, fascia, and skin should be approximated with through-and-through rubber-shod wire sutures. For better approximation, a few interrupted catgut sutures may be placed in the fascia between the wire sutures. More accurate skin approximation can be obtained with an occasional interrupted silk suture.

The technic of treatment of wounds of the rectum, kidney, ureter, bladder and arteries is a part of another discussion.

Results

During the final 3 months (1 May to 1 August 1953) of the Korean conflict, a statistical data sheet was made out on all general surgical casualties admitted to the 46th Surgical Hospital. The data collected from these records have been used to compile statistics for a detailed study of the casualty's care from the time of his admission to his discharge. During this period, 75 patients were admitted with abdominal wounds and 29 with thoraco-abdominal injuries (table 1). Nine

Table 1. Mortality and Mode of Evacuation

Type of wound	Total	Deaths	Mortality (percent)	Evacuation		
				Ambulance	Helicopter	Not stated
Abdominal	75	9	12. 0	40	27	8
Thoraco-abdominal	29	3	10. 3	19	8	2
Total	104	12	11. 5	59	35	10

deaths occurred among those with abdominal injuries, a mortality rate of 12 percent. Three deaths occurred in the patients with thoraco-abdominal injuries, a mortality rate of 10.6 percent. There is essentially no difference in the mortality rate of these two types of wounds.

Fifty-nine patients were evacuated by ambulance and 35 by helicopter. In 10 cases, the mode of evacuation was not stated. The percentage of casualties evacuated by helicopter in the abdominal group was slightly higher than in the thoraco-abdominal group. In most instances the helicopter was used to evacuate the most seriously wounded.

Time Interval

In the 75 abdominal casualties, the time from injury to admission to the hospital was 3.1 hours (table 2). The length of time required to prepare the patients for operation was practically the same. Thus there was an average time interval of 6.3 hours from injury until operation.

Table 2. Time Intervals

Type of wound	Number of cases	Hours injury to admission	Hours admission to surgery	Hours injury to surgery	Operative time (hours)
Abdominal	75	3. 1	3. 2	6. 3	2. 4
Thoraco-abdominal	29	4. 7	2. 7	7. 9	2. 3

The casualties with thoraco-abdominal injuries had a greater time interval from injury to admission to the hospital (4.7 hours), but a shorter period of time was required for resuscitation for operation (2.7 hours). Difference in the time interval was probably due to the greater number of them that were evacuated by ambulance. Essentially there was no difference between the two groups in the operative time (2.3 hours).

Average Amount of Blood Required in Resuscitation

An analysis of the amount of blood given to the abdominal and thoraco-abdominal patients during resuscitation was made (table 3).

Table 3. Average Blood Administered During Resusitation

Type of wound	Total number of cases	Blood prior to admission (cc.)	Blood prior to operation (cc.)	Blood during operation (cc.)	Average amount of blood first 24 hours (cc.)
Abdominal*	75	264	1, 464	1, 467	3, 428
Thoraco-abdominal	29	103	1, 308	1, 187	2, 867

*Patients receiving 40, 46, 52, and 56 pints excluded.

It was shown that the amount of blood (3 pints) given during the preoperative period to casualties sustaining abdominal wounds was approximately equal to the amount given during the operation. The patients who had thoraco-abdominal wounds received a slightly higher amount of blood preoperatively (1,308 cc.) than during the operation (1,187 cc.). About 7 pints of blood (3,428 cc.) was required in the first 24 hours by patients with abdominal wounds. Those with thoraco-abdominal wounds required 2,867 cc. of blood during this period. Patients who received 40, 46, 52, and 56 pints of blood respectively during their first 24-hour period were not included in these figures. It was felt that, by excluding them, a more accurate estimate of the average amount of blood required could be obtained. Most of the casualties received from 1 to 6 units of blood in the first 24 hours.

Causes of Death

There were nine deaths in the abdominal group (table 4). Five patients died from uncontrolled hemorrhage, two died of peritonitis and one each from aspiration pneumonia and pancreatitis. Two of the patients who died of uncontrolled hemorrhage died during operation. In one patient the common iliac artery was severed. He had a large retroperitoneal hematoma. Upon opening the peritoneum over the hematoma, active bleeding was controlled promptly; however, the patient went into immediate shock and died even though large quantities of blood were given, 19 pints in 4 hours. One patient died of cardiac arrest following prolonged hemorrhage; operation was delayed for 10 hours because of the heavy casualty load. The three other patients who died of uncontrolled hemorrhage had massive wounds of the muscle. They received 40, 52 and 56 pints of blood respectively in the first 24 hours. These patients had extensive muscle damage and illustrate the difficulty of controlling hemorrhage in such cases.

One patient died of aspiration pneumonia. During his evacuation by helicopter, he aspirated vomitus. Bronchoscopy was done on numerous occasions, but without improvement. His case points out the importance of emptying the stomach of its contents as soon as possible after injury. Two patients died of peritonitis. Both had injuries of the cecum. One had an additional injury to the duodenum, while the other had an additional injury of the small bowel. One patient died of pancreatitis; this patient might have been saved by a resection of the tail of the pancreas or better drainage of the area.

Thoraco-Abdominal Group

There were three deaths in the thoraco-abdominal group, one each from cardiac arrest, postoperative shock and hemorrhage from a lacerated liver (table 4). All died within the first 39 hours after injury. All had wounds of the right side of the diaphragm with associated liver damage. One patient had an extensive laceration of the liver which was repaired; and hemorrhage appeared to be controlled at operation.

Table 4. Causes of Death

Abdominal:		
75 cases, 9 deaths	Uncontrolled hemorrhage	5
	Peritonitis	2
	Aspiration pneumonia	1
	Pancreatitis	1
Thoraco-abdominal:		
29 cases, 3 deaths	Uncontrolled hemorrhage	1
	Postoperative shock	1
	Cardiac arrest	1

A secondary hemorrhage from the liver occurred several hours after operation and caused his death. Another patient had extensive injuries of the liver, duodenum and ileum. It was impossible to maintain a satisfactory blood pressure at any time during or following his operation. It was thought that continued hemorrhage caused his death. The remaining patient with extensive liver and chest injuries had a cardiac arrest during operation; the heart was massaged until return of normal rhythm. Twenty-nine hours after his operation, the patient had another cardiac arrest and died.

Negative Explorations of the Abdomen

No intra-abdominal injury was found in 36 (9.2 percent) of the 391 patients who had abdominal operations (table 5). Prior to operation, it is sometimes difficult to be certain that an abdominal viscus had not been perforated. This is especially true when the shell frag-

Table 5. Negative Explorations of the Abdomen

Investigators*	Number of laparotomies	Negative laparotomies	Percent negative laparotomies
Pearson, Tuhy, and Welch—1945, American-Northern Europe	290	23	7. 9
O'Gilvie—1942–43, British-Western Desert	247	42	17. 0
Edwards and Stead—1944, British-Italian Campaign	560	66	11. 8
Porritt—1944–45, British	4, 319	740	17. 1
46th Surgical Hospital—1952–53, Korea	391	36	9. 2

*See references.

ments have entered the abdominal wall anteriorly and lie close to the peritoneum. Many times, fragments that have entered the back or the perineum present the same problem. When it cannot be established that a viscus has been perforated, an exploratory operation should be performed. Our experience compares favorably with that of Welch in World War II who reported negative laparotomies in 7.9 percent of 290 operations (*2*). In various campaigns of World War II, the British reported negative abdominal explorations varying from 11.8 to 17.1 percent (*3*).

Comparative Statistics for Mortality of Abdominal Wounds

A study of 384 casualties who had abdominal wounds, covering a 17-month period in Korea, was compared with patients having similar injuries from the Second Auxilary Surgical Group in World War II (*4*). This number includes the 75 casualties discussed at the beginning of this report. A comparison, by organs, shows that the colon, jejunum, ileum and liver were the most commonly injured during both the Korean conflict and World War II (table 6). The stomach, kidney and spleen were the second most commonly injured organs. In those instances in which injury occurred to more than one organ, the mortality rate in Korea was approximately one-half of the mortality rate in World War II. The mortality rate was approximately the same for injuries to the duodenum and the ureter.

Mortality of Thoraco-Abdominal Wounds by Side of Body Affected

There were 72 casualties in the Korean conflict who had thoraco-abdominal wounds with perforation of the right side of the diaphragm (table 7). Twelve of these patients died, a mortality rate of 16.6 percent. The Second Auxiliary Surgical Group of World War II reported 103 deaths among 435 casualties, a mortality rate of 24 per-

*Table 6. Comparative Statistics of Mortality Rates for Abdominal Wounds by Organs—Korea, 1952–53, and World War II, 1942–45 **

Viscus	Korea				World War II			
	All cases, deaths		Complicated, percent dying	Uncomplicated, percent dying	All cases,* deaths		Complicated, percent dying	Uncomplicated, percent dying
	Number	Percent			Number	Percent		
Colon	140	15. 0	18. 5	9. 3	1, 106	37	41	23
Jejunum and Ileum	134	13. 4	16. 4	3. 0	1, 168	30	36	14
Liver	102	15. 6	20. 6	9. 0	829	27	39	10
Stomach	45	17. 5	22. 8	0	416	41	42	29
Kidney	55	25. 4	29. 1	0	427	35	38	16
Spleen	54	15. 0	18. 6	0	341	25	30	12
Rectum	22	18. 1	16. 0	11. 7	155	30	42	14
Bladder	21	9. 4	13. 3	0	155	30	34	0
Duodenum	17	41. 1	43. 7	0	118	56	56	50
Pancreas	9	22. 2	25. 0	0	62	58	57	100
Gallbladder	33	0	0	0	53	30	30	0
Ureter	4	50. 0	50. 0	0	27	41	42	0

* Second Auxiliary Surgical Group from Beebe and DeBakey

cent (*4*). In 57 patients, the left side of the diaphragm was perforated; a mortality rate of 8.7 percent as compared with a mortality rate of 30 percent in World War II. The mortality rate of all wounds of both sides of the diaphragm was 13.1 percent for Korea as compared with 27 percent in World War II. In Korea, wounds of the right side of the diaphragm carried a higher mortality rate than those of the left side, probably because of injury to the liver. In World War II, there was a mortality rate of 24 percent for wounds of the right side and 30 percent for wounds of the left side (*4*).

Table 7. Comparative Statistics of Mortality Rates for Thoraco-abdominal Wounds by Side of Body Affected

Theater	Right diaphragm			Left diaphragm			Total		
	Number wounded	Deaths		Number wounded	Deaths		Number wounded	Deaths	
		Number	Percent		Number	Percent		Number	Percent†
Korea, 1952–53	72	12	16. 6	57	5	8. 7	129	17	13. 1
World War II,* 1942–45	435	103	24. 0	448	136	30. 0	883	239	27. 0

*Second Auxiliary Surgical Group from Beebe and DeBakey.
†Chi Square Test=10.8; P=0.001.

Comparative Statistics for Abdominal Wounds by Number of Organs Damaged

A direct comparison of the number of organs damaged was made between those casualties with abdominal wounds in Korea and those from World War II (table 8) (*4*). It was felt that this would be an accurate comparison, since it was based on the number of organs injured. There was little difference in the time interval from injury to operation: in World War II, from zero to 7 hours; in Korea, an average of 7 hours.

Table 8. Comparative Statistics of Mortality Rate for Abdominal Wounds By Number of Organs Damaged

Number of abdominal organs hit	Korea—Injury to operation, average 7 hours		World War II—Injury to operation,* 7 hours or less		Statistical tests for significance of difference
	Number wounded	Percentage dying	Number wounded	Percentage dying	
0	36	2. 8	98	5	Chi Square analyzed according to number of abdominal organs injured gives: X^2 (5) = 11.95 0.05 P 0.02
1	181	6. 62	496	10	
2	102	6. 82	402	24	
3	45	26. 6	132	42	
4	12	8. 3	41	54	
5	6	16. 0	13	92	
6	2	50. 0	3	100	
Total	384	10. 68	1, 185	20. 51	Overall statistics: $\frac{X}{S.D.} = 4.35$ P 0.0003

*Second Auxiliary Surgical Group from Beebe and DeBakey.

The casualties without organ damage had essentially the same mortality rate. Little difference was seen in the mortality rates of casualties who had four, five, or six organs damaged. There was a significant difference between the overall mortality of 10.68 percent in Korea and 20.51 percent in World War II. Although there was little difference in the slightly wounded (no organ damage) and the most severely wounded (four, five, or six organ damage), the significant differences in the moderately wounded (one, two, or three organ damage) and the overall mortality rate points out the improved results achieved in Korea.

Summary

A study of the casualties who had abdominal and thoraco-abdominal wounds was made at the 46th Surgical Hospital in Korea.

The surgical technics proven to be acceptable in the management of these casualties have been outlined.

The average time from injury to admission for casualties with abdominal wounds was 3.1 hours; for thoraco-abdominal wounds, 4.7 hours. The abdominal casualties received an average of 3,400 cc. of blood and the thoraco-abdominal casualties received an average of 2,800 cc. of blood in the first 24 hours after injury. More than half of the deaths were caused by uncontrolled hemorrhage.

The mortality rate for 129 thoraco-abdominal casualties in the last year and a half of the Korean war was 13.1 percent. In World War II the mortality rate for 883 casualties with thoraco-abdominal wounds was 27 percent.

The mortality rate for 384 casualties who had abdominal injuries in Korea was 10.68 percent. In a series of 1,185 casualties who had comparable organ damage and comparable evacuation times treated by the Second Auxiliary Surgical Group, the mortality rate was 20.51 percent.

Acknowledgment

Some of the data pertaining to the Korean conflict in tables 6, 7, and 8 were compiled from the records of Captain John Howard and Captain Frank Inui.

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FRIDAY MORNING SESSION

23 April 1954

MODERATOR

LIEUTENANT COLONEL CARL W. HUGHES, MC

SURGICAL CONSIDERATIONS IN THE TREATMENT OF WAR WOUNDS OF THE RECTUM AND RECTOSIGMOID COLON*

LIEUTENANT COLONEL H. HASKELL ZIPERMAN, MC

Introduction

Wars tend to increase in lethality through the discovery of new weapons of destruction and the application of old concepts of warfare in a newer and more deadly fashion. Always parallel with and tending to act as a limiting factor in this destructiveness is the introduction of new medical and surgical principles which save life and decrease morbidity. That this applies is shown by the decreasing mortality among casualties reaching medical attention in World War II as compared with the Korean war—4.5 percent in the former as compared with 2 percent in the latter.

In the Korean war, principles of the management of battle casualties learned in preceding wars were applied. Changes were made as experience and new technics necessitated. Since the war-free interval from the end of World War II to the beginning of the Korean conflict was short, much of what was learned in the former was applied in the latter with little change. This was especially true in the handling of casualties with penetrating wounds of the abdomen and perforations of bowel. That some changes were made will be evident by comparing this paper with the discussion of rectal and rectosigmoid injuries in TB Med 147.

Diagnosis

Perhaps the first clue found in a casualty who had suffered a penetration of the rectum or rectosigmoid was the site of the wound of entrance, and in some cases the location of the wound of exit. It was possible by projection in cases with wounds of exit and entrance to mentally visualize the missile tract and coupled with physical findings to determine the organs damaged. All penetrating perineal, buttocks, and low abdominal and back wounds were considered as potential sources of wounds of the rectum and rectosigmoid until proven otherwise.

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When first seen, the patient with a penetrating wound of the peritoneal cavity with massive fecal contamination of the peritoneum presented a picture of shock which was difficult to differentiate from that due to severe blood loss. In fact, in cases with wounds of the peritoneal cavity the attempt to make this clinical differentiation was purely academic since exploration was essential to determine the true extent of involvement and to institute proper treatment. It was generally agreed by all surgeons in the Korean Theater that the most profound and unresponsive shock picture seen among battle casualties was that among wounded with severe and continuing hemorrhage and those with massive fecal contamination of the peritoneal cavity.

The shock picture in the patient with an extraperitoneal perforation of the rectum was totally different. Here the casualty was rarely in shock unless there were associated injuries of sufficient severity to cause a marked drop in blood pressure. As can be surmised, it was impossible to determine bowel perforation on the basis of shock alone.

In the emergency surgical hospitals in the combat zone in Korea as soon as the possibility of peritoneal penetration was entertained, a Levin tube was introduced into the stomach both to ascertain whether bleeding was present and to empty the stomach; a catheter was introduced into the urinary bladder to rule out damage to the genitourinary tract; and inspection, palpation, percussion and auscultation of the abdomen were carried out. Typically the casualty with intraperitoneal perforation of the gastrointestinal tract showed mild to moderate abdominal distention associated with tympany, abdominal rigidity and absent bowel sounds. Clinically it was difficult to determine whether the abdominal distention was due to paralytic ileus with accumulation of gas, intraperitoneal hemorrhage, or both. Some of these casualties were in such a severe state of shock that all muscular tonus was decreased and consequently no abdominal splinting was present.

In wounds of the extraperitoneal portion of the rectum there was rarely any abdominal distention unless there was an associated perforation of the bladder or great vessels so that low abdominal distention was produced by extravasation of blood or urine or both into the pelvic tissues and peritoneal cavity. This extravasation was rare and easily differentiated from true abdominal distention.

As frequently as not a digital rectal examination added considerable information with regard to lower colon and rectal perforation and associated injuries of pelvic structures. The presence of blood in the cul-de-sac could be determined by bulging into the rectum. A low rectal perforation could actually be palpated in this manner. In any instance where blood was found on the palpating finger when withdrawn, it had to be assumed that either a rectosigmoid or rectal

perforation existed since rarely did perforations higher in the descending colon produce blood in the rectum in the short time elapsed between wounding and admission to the surgical hospital in the Korean experience.

X-ray examination was considered to be the best adjunctive method for determining which organs and viscera had been damaged. For good localization, both AP and lateral examinations were essential. Knowing the site of the wound of entrance, it was possible, on the basis of the position of the retained metallic foreign bodies in relation to the known position of organs and viscera, to determine at least moderately well which structures had been damaged. Where there was both a wound of entrance and exit, the position of retained metallic foreign bodies allowed for a reasonably accurate estimation of the structures damaged. Where multiple wounds were present, as so frequently happened, it was difficult to determine which retained missile was responsible for the particular wound but here its localization in the vicinity of a specific structure was helpful in determining the particular structure injured.

In those casualties in whom all other methods of determining whether a vital structure was injured had failed, it was found that débridement of the wound tract proved to be particularly useful. This maneuver consisted in débriding the successive layers of the wound until the missile was found and removed, or until it was determined that penetration of the peritoneal cavity existed or that a vital structure was injured. This procedure was an adjunct to definitive laparotomy and was performed prior to that surgery and after the casualty had been prepared as if for definitive surgery. This maneuver was reserved only for casualties in whom there was a question of penetration of the peritoneal cavity or of injury to a vital structure in the pelvis and saved time and morbidity since an unnecessary laparotomy was thus avoided.

Sigmoidoscopic examination as a means of making the diagnosis of rectal injuries was used as an adjunct to all of the other modalities of diagnosis. All casualties with wounds of the pelvis and buttocks and those in whom blood was found on the examining finger on digital rectal examination were subjected to sigmoidoscopy. These patients were prepared for laparotomy but sigmoidoscopy was done prior to definitive surgery by placing them in the Sims' position on the operating table. This procedure was found to be especially useful in those individuals with an extraperitoneal perforation of the rectum since extensive dissection and mobilization of the rectum could usually be avoided when the exact site of perforation was known in advance. In the presence of blood on the examining glove after digital rectal examination, a negative sigmoidoscopic examination was never taken

as evidence that rectal injury did not exist, since the blood could either have been from a point which could not be reached by the scope or a perforation might have been overlooked during the examination.

In the ultimate analysis the only absolute method of determining rectal or rectosigmoid injury in a battle casualty whose symptoms and signs were questionable was by performing a laparotomy. While it is true that occasional unnecessary laparotomies were thus performed, these were held to an absolute minimum by first utilizing all of the other diagnostic modalities in each case.

Treatment

It was found expedient in performing a laparotomy on casualties to adopt a relatively standard routine for exploration. Knowing the wound of entrance and having received information from x-ray examination as to the position of fragments within the peritoneal cavity, it was easy to decide where the first focus of attention should be placed on opening the peritoneum. In every instance where a large amount of free blood was found in the peritoneal cavity, it was felt to be expedient to search first for the bleeding source so that it could be controlled by hemostat or pack depending on the amount of blood being lost and the source of the bleeding. Having controlled the bleeding point, attention was then paid to the intra-abdominal organs. A start was made at the point where known injury existed. As soon as the extent of injury at the wounding site had been determined, the entire small bowel was quickly run from the ligament of Treitz to the ileocecal valve, or vice versa, with each perforation being marked. Where indicated by the known path of the missile and its tract, both ascending and descending colon were then reflected towards the midline so that retroperitoneal as well as peritoneal surfaces of the bowel could be examined. In all instances in which injury to the rectum or rectosigmoid was expected but not found, it was deemed advisable to open the pelvic peritoneum and to mobilize and explore the rectum in the hollow of the sacrum. Where carried out, this procedure was performed in such a manner as to allow adequate visualization of all surfaces of the rectum down to the point of attachment of the levator ani muscles.

In all instances where a perforation of the rectum or rectosigmoid was found, all other pelvic viscera, including the urinary bladder, ureters, accessory genital organs and great vessels were visually inspected because of the frequent association of injuries of these structures with wounds of the colon in this region. It was axiomatic that where a single perforation of a hollow viscus was found a second perforation likewise would be found unless the surgeon could prove to his satisfaction either that the injury was due to concussion, that

only penetration had occurred and the fragment was retained within the hollow viscus, or that a glancing wound with single penetration had occurred.

Whenever a wound of the rectum or rectosigmoid was found, it was felt advisable to close the perforation in two layers if at all possible. Where a large segment of rectosigmoid was destroyed it was occasionally necessary to effect closure by a sleeve type of resection, reestablishing continuity by mobilizing the proximal bowel so that suturing could be done without tension.

Since most of these wounded had fecal material in the colon at the time of wounding, it was usual to find fecal contamination of the peritoneal cavity in casualties with wounds of the rectum and rectosigmoid. It was deemed advisable where contamination of the peritoneum had occurred, to wipe the area free of gross material but not to drain the area after suture of the bowel. Where the wound was extraperitoneal, the peritoneum was closed after exploration and suture of the bowel, and the pre-sacral space was drained, bringing the drain out at a point just anterior to the coccyx. It was necessary at times to remove the coccyx to secure adequate drainage. Where it was felt advisable to do so, a tract for the drain was established in the pre-sacral space from above and the drain inserted by incising the skin from below at the conclusion of the laparotomy.

The use of colostomy as an adjunct for treatment of wounds of the colon became well established during World War II and was carried over into the Korean war. Wounds of that portion of the colon which could be treated by exteriorization of the perforated colon over a glass rod were routinely handled in this way. Wounds of the rectum or rectosigmoid where exteriorization could not be accomplished were treated by a proximal diverting colostomy with the proximal loop being placed caudad to the distal one. It became routine during the Korean war to bring out the sigmoid colon as a diverting colostomy through a left McBurney muscle-splitting incision. The loop was actually divided, the clamps being left in place to keep the ends of the bowel closed, and the ends were separated by closing at least peritoneum and skin between them. It was felt that this served to prevent any spill of feces from the proximal to the distal bowel. No attempt was made to produce a spur for later crushing. Although some surgeons brought the two ends of bowel out through individual stab wounds separated by at least 2 to 3 inches of intact skin, it was felt that this maneuver served to make ultimate closure of the colostomy more difficult unless the two stab wounds were carefully placed with respect to the direction of the line of fibers of the fascial layers. Sutures were never used between the bowel and the abdominal wall for fear of placing the sutures too deep and causing a fecal fistula.

Instead, dry gauze was placed around the exteriorized bowel near its termination to prevent it from retracting into the peritoneal cavity. The clamp was left across the proximal bowel end for at least 24 hours to assure an adequate seal between the parietal peritoneum and the bowel serosa. The colostomy wound was separated from the laparotomy wound by means of water-tight dressings, and in those instances where an associated bladder injury was present necessitating a drainage of the space of Retzius, care was taken to bring this out through a stab wound completely separated from all other incisions.

The vogue, so popular in World War II, of dusting sulfa powder and/or antibiotics liberally into the peritoneal cavity was completely discontinued during the Korean war without deleterious effect. Because of the availability of antibiotics at all echelons of medical care in Korea, all casualties received penicillin at the same time they received their tetanus toxoid at battalion aid stations. Most of these casualties received 600,000 units of procaine penicillin as an initial dose but in the closing months of the war some question arose as to whether or not an effective blood concentration could be produced by this dosage and it was finally decided to increase this initial dose to 1 million units of crystalline penicillin.

When casualties with penetrating abdominal wounds and intraperitoneal trauma were received and operated upon at surgical hospitals in Korea, a routine part of their postoperative care consisted in the administration of antibiotics. Almost without exception the parenteral use of penicillin was continued, potentiated either by streptomycin or intravenous aureomycin or terramycin, depending on the specific preference of the surgeon. While earlier in the war the combination of penicillin and streptomycin was used almost to the exclusion of other antibiotics, during the last year of the war more and more surgeons were shifting to the combination of penicillin and either aureomycin or terramycin. Without the availability of statistical data, it is impossible to state whether this produced any significant change in morbidity or mortality figures. Again some question arose as to the efficacy of the antibiotics used in the dosages administered. A research team in the area in the closing months of the war recommended larger dosage in order to obtain more effective blood concentrations of the various antibiotics.

Mistakes and Complications

Perhaps the commonest mistake seen in the handling of casualties with wounds of the rectum and rectosigmoid colon in the Korean Theater was lack of recognition that this type of wound was present. This oversight was encountered most frequently in those casualties who had suffered retroperitoneal trauma so that the site of injury

could not be seen unless the bowel was mobilized. Commonly this resulted in a pelvic or pararectal abscess, as frequently as not associated with a fecal fistula along the missile tract. In at least one instance known to the author this resulted in a peritonitis with adhesions and repeated obstructions of the small intestine.

Less frequent were those instances in which the pre-sacral drain was not placed deep enough in the pelvis or where by some oversight the pre-sacral space was not drained at all. These errors commonly led to deep retroperitoneal or pararectal suppuration so that adequate drainage had to be instituted. In a few instances, after débridement of the missile tract, drains had been placed down to the rectum or rectosigmoid along these tracts. This type of drainage especially in those casualties in whom the wound of the colon was not sutured led to a particularly intractable sinus tract infection with prolonged morbidity and convalescence.

Occasionally an inexperienced surgeon would bring at least the distal colostomy loop out through some part of the laparotomy wound. Almost inevitably this led to wound infection and breakdown. It was therefore felt to be absolutely mandatory to insist not only that the colostomy be brought out through a separate incision but that it also be separated from the laparotomy wound by some type of waterproof dressing.

The problem of adequate diversion of the fecal flow in wounds of the rectum and rectosigmoid was not solved until midway through the Korean war. It was found that the term "diverting colostomy" meant different things to different surgeons. After several casualties with rectal wounds were found to have simple loop colostomies with no diversion of the fecal stream from the suture line in the bowel, it was felt necessary to insist that diverting colostomies be so constructed that the two bowel ends were separated by 2 or more inches. General acceptance of this procedure decreased markedly the incidence of fecal fistula resulting from spillage of fecal material from the proximal into the distal bowel.

In the last three wars in which the United States has engaged, there has been a progressive decline in the mortality rate among battle casualties reaching medical attention. The exact reason for this decline is hard to pinpoint but most observers are in agreement that two of the more important factors are availability and utilization of various antibiotics, and speedy, nontraumatic evacuation of seriously wounded casualties to surgical hospitals. (The time lag between wounding and surgery of 58 casualties in World War II was 15.2 hours as compared with 9.95 hours for 62 casualties in the Korean war.) Although statistics for this latest war have not yet been analyzed, it is probably logical to assume that along with the overall

decrease in mortality there was probably also a decrease in the mortality associated with wounds of the rectum and rectosigmoid colon. Due credit for the methods of handling this type of casualty must be given to the surgeons of World War II who evolved so much of this routine of management by trial and error based on experience.

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PRIMARY SURGERY OF BLOOD VESSELS IN KOREA*

An Analysis of Major Artery Repairs in Korea During 1953

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The damage to extremity blood vessels constitutes a small but important component of war wounds. Of 2,471 such wounds collected by DeBakey and Simeone (*1*) from World War II, 49.6 percent of those with involvement of a major artery came to amputation. Ligation of damaged vessels was the accepted practice. They further reported 81 cases in which suture of the artery was performed. In these, the amputation rate was 35.8 percent.

Shortly after the beginning of the Korean conflict, Walter Reed Army Hospital was designated as the peripheral vascular surgery center for the Army and received a substantial number of Army personnel who had sustained traumatic arteriovenous fistulas and aneurysms. The results of reparative and reconstructive surgery of many of these lesions have been reported (*2–4*). On the basis of this experience, the feasibility of primary repair of damaged major blood vessels of extremities was considered practical. Personnel trained in the technic of blood vessel repair were sent to Korea as members of the Surgical Research Team of the Army Medical Service Graduate School for this investigation and the practicability of repair of major arteries of extremities as part of the definitive surgery of war wounds was established. A total of 130 major vessel injuries were repaired, followed and reported by three members of the Surgical Research Team (table 1), (*5–7*). The average amputation rate for these 130 vascular repairs was 10.8 percent.

Ziperman (*8*) analyzed the results of 234 major and minor arterial wounds collected and followed within the theater during the first 9 months of 1952 in Korea. His report includes the work of two members of the Surgical Research Team. He compared the overall findings in his collected group to the results reported by DeBakey and Simeone and reported 127 major arteries repaired by suture with an amputation rate of 20.5 percent. This represents a 42.7 percent de-

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Table 1. Controlled Follow-up Studies—Major Artery Repairs—Korea, 1952 and 1953

Investigator	Cases	Amputations	
		Number	Percent
Jahnke (1952)	34	3	8. 8
Howard (1952)	24	3	12. 5
Hughes (1953)	72	8	11. 1
Total	130	14	10. 8

crease in amputation rate; however, both of these series are based on relatively small numbers.

The purpose of this communication is to report an analysis of all major vascular wounds repaired in Korea from 1 January through July 1953 (exclusive of Navy and Marine personnel) during which time 211 major arterial injuries were detected in 205 patients. Two patients had three vascular injuries each and two patients had two injuries each. Seventy-two of these vascular injuries (table 1) were treated by the author and have been reported in detail (*5*).

Materials and Methods

Reports on all cases in the Korean Theater were centralized in the Office of the Surgeon of the Eighth U. S. Army. Three reports emanated from the forward hospitals in which the surgery was performed and from the evacuation hospitals through which these patients later passed.

The results are tabulated as immediate and late. Such division has been necessary because this series includes 61 Korean national and prisoner of war patients and other United Nations personnel many of whom were lost to late followup once they left surgical and evacuation hospitals of the U. S. Army. Late followup studies were accomplished on other Allied patients as they were returned to vascular centers in Japan and on American patients as they were returned to Walter Reed Army Hospital, where they were subsequently evaluated by arteriography, oscillometry, skin temperature and exercise tolerance studies.

In this overall theater total of 211 major vascular injuries, deaths were reported as occurring from causes other than the arterial injury, in 15 patients with 18 arterial repairs. Arteries involved in these patients were the carotid 1, axillary 1, common iliac 1, femoral (unqualified) 3, common femoral 2, superficial femoral 3, and popliteal 7. Since an adequate evaluation of the arterial repairs in these patients

was not possible, these 18 repairs have been eliminated, leaving 193 repaired major vascular injuries in 190 surviving patients.

Regardless of efforts made to follow every patient, 62 of the 193 repairs in surviving patients were lost to long-term followup studies because of evacuation of the patients to Korean or U. N. hospitals after operation. Thus, 193 arterial injuries were available for short-term studies and of these, 131 came to later followup studies.

Approximately 85 percent of the vascular wounds were caused by fragmenting missiles and 15 percent by nonfragmenting missiles. Of all the vessels damaged, most were lacerated with almost an equal number severed. Only a few vessels were thrombosed or in spasm (table 2). The lower extremity was the most prevalent site of vascular injury (55.5 percent) with the upper extremity a close second (38.4 percent), while the neck and trunk received a very low percentage of the injuries. A distribution of injuries is shown in table 3.

Table 2. Major Vascular Injuries—Korea 1953

Type of injury	Number	Type of injury	Number
Lacerated	113	Spasm	2
Severed	89		
Contusion and thrombosis	7	Total	211

Table 3. Total Major Vascular Repairs—Korea 1953

Body region	Artery	Number	Percent
Neck	Carotid	7	3. 3
Upper extremity	Axillary	13	38. 4
	Brachial	68	
Trunk	Aorta	1	2. 8
	Common iliac	3	
	External iliac	2	
Lower extremity	Common femoral	12	55. 5
	Superficial femoral	68	
	Popliteal	37	
Total		211	100. 0

Data available from approximately one-third of the patients in this report showed that 40 percent of the group arrived in shock of varying degree and 47 percent of the group had a tourniquet applied for an average of 4 hours.

Those with vascular injuries received a high, but not first, priority evacuation unless there was uncontrolled hemorrhage or profound

shock which could not be treated prior to evacuation. The average time lag from injury to surgery for all cases of vascular injury in 1953 averaged 9.8 hours, almost identical to what it was in 1952 as reported by Ziperman. Approximately 6 hours of this time was spent reaching the hospital and 4 hours in preparation for surgery. This is a reflection of the degree of injury and shock in these patients.

An anatomical surgical approach was used regardless of location of the wound. An adequate incision was always made and proximal control of the damaged vessel secured first. After excision of the damaged portion of the vessel, repair was accomplished by a continuous mattress suture with 00000 braided arterial silk everting the edges of the artery, apposing intima to intima.

Most of the repairs (64.8 percent) were accomplished by direct anastomosis; with autogenous vein grafts (14.5 percent), the second most common type of repair. Lateral suture repair followed in the third place and homologous arterial grafts in the fourth place (table 4). Conservative nonoperative treatment was practiced in some instances of nonexpanding pulsating hematomas especially of the carotid artery. Ligation was utilized only where repair was not feasible in a noncritical artery or when the patient's condition did not permit further surgery.

*Table 4. Type of Repair, Major Vascular Wounds—Korea 1953**

Repair	Number	Percent	Repair	Number	Percent
Anastomosis	125	64. 8	Release spasm	2	1. 0
Vein graft	28	14. 5	Remove thrombus	1	0. 5
Artery graft	11	5. 7	Ligation	3	1. 6
Lateral repair	19	9. 8			
Conservative	4	2. 1	Total	193	100. 0

*Excluding 18 repairs in patients who died.

After careful débridement, care was taken to cover the repaired vessel in order to nourish and protect it but the wound was left open for drainage and to minimize the risk of infection. Penicillin and streptomycin were used routinely in all patients. Sympathectomy was not practiced and anticoagulants were not utilized. Following surgery, only those extremities with complicating fractures were placed in casts. For a period of 2 weeks only limited active motion was permitted at the vascular repair site. If the wound remained clean, delayed closure was accomplished on the fourth to sixth postoperative day.

Results

Of the total 193 vascular repairs in surviving patients, 26 amputations resulted. These amputations were done following repairs of the axillary artery in 2 cases, brachial artery (unqualified) 2, femoral (unqualified) 4, common femoral 5, superficial femoral 2, and popliteal 11, most of which are considered as critical arteries. The percentage of amputations was higher in those cases requiring grafts for repairs (table 5).

*Table 5. Short-term Followup—Total Major Vascular Repairs—Korea 1953**

Repair	Total—Number	No Amputation				Amputated		Died—Number
		Good		Thrombosed				
		Number	Percent	Number	Percent	Number	Percent	
Anastomosis	136	95	84. 8	17	15. 2	13	10. 4	11
Vein graft	30	14	70. 0	6	30. 0	8	28. 6	2
Artery graft	12	3	37. 5	5	62. 5	3	27. 3	1
Lateral repair	20	17	94. 4	1	5. 6	1	5. 3	1
Conservative	4	4	------	0	------	0	------	0
Release spasm	2	1	------	0	------	1	------	0
Remove trombus	1	1	------	0	------	0	------	0
Ligation	6	3	------	0	------	0	------	3
Total	211	138	82. 6	29	17. 4	26	13. 5	18

*Percentages exclude patients who underwent amputation or died.

Causes for amputation were determined where possible. Seven patients were reported as having good blood flow through necrotic muscle at the time of amputation. The muscle had undergone irreversible changes prior to reconstruction of the artery. Thrombosis was responsible for three amputations, compression of the repaired vessel by a displaced compound comminuted fracture was responsible for one amputation and venostasis was responsible for another. The reason for amputation in the remaining 14 was not recorded. Of these, five limbs were amputated over varying periods of several days to 3 months following repair of the damaged artery. In one case reported here as an amputation, the patient lost only four toes while another had a transmetatarsal amputation.

An attempt was made to correlate the rate of amputation with the presence of compound comminuted fractures but the findings are not significant. As may be expected, however, there was a direct correlation between rate of amputation and size of the wound.

Complications were encountered much less frequently than was expected. Hemorrhage from the suture line was quite rare. Infection at the repair site, which may result in hemorrhage or thrombosis, was rarely a problem. Latent thrombosis probably occurs more frequently than is realized but the thrombus is often slow in formation during which time the collateral circulation increases and compensates for the major artery, thereby preventing limb loss.

One of the greatest determining factors in the final results of arterial repair is the time dapse from arterial injury to repair. Even this can be quite variable depending on many factors such as size of the wound, number of collaterals involved, level of the artery involved, ambient temperature, severity of shock and antomical variations. Although it has been shown that results are proportionally better when arterial repair is done within 10 hours of injury, an extremity may undergo irreversible muscle changes much earlier or remain viable much longer, depending on the above factors. The author has previously reported five cases in which major arterial injury was repaired 11 to 24 hours (an average of 16 hours) after injury. At the time of amputation, all five extremities exhibited good blood flow through necrotic muscles. It was considered that time lag from injury to surgery was a significant factor in those five cases.

The time from injury to repairs in the 26 patients whose extremities subsequently required amputation varied from 1 to 24 hours with a mean of 10.5 hours; almost identical with the average time lag of 9.8 hours recorded for the entire series.

Numerous patients were seen with the injured limb cold, ischemic, anesthetic and paralytic, with the joints fixed. After arterial repair, as these limbs became warm and sensation and motion returned, they often began to swell, requiring fasciotomy. When fasciotomy was delayed, all degrees of muscle necrosis occurred, varying from microscopic areas of focal necrosis to loss of complete compartments. The flexor compartment of the forearm and the anterior tibial compartment of the leg seemed to be most vulnerable.

Short-term Followup

If analogous groups of cases are compared after only the limited theater followup studies, then we find that there were 127 major artery repairs in 1952, reported by Ziperman, with 26 cases, or 20.5 percent, resulting in amputation. Of the 193 major artery repairs with limited followup studies in this report from 1953 there were also 26 cases, or 13.5 percent, which resulted in amputation; an improvement of 34.1 percent in limb survival during the last year of the Korean war.

Thrombosis was reported as occurring in 29, or 17.4 percent, of the total surviving unamputated patients with limited studies (table 5). No arteriograms were done in these patients during their short-term studies. Thrombosis was considered as occurring when no pulse returned following arterial repair or when a pulse had been present postoperatively and later disappeared Failure of a pulse to return following surgery may have been the result of faulty technic rather than thrombosis but the consequences are the same. Excluding the patients who underwent an amputation or died, thrombosis occurred in 15.2 percent of the vessels repaired by direct anastomosis, in 30.0 percent of those repaired by autogenous vein grafts and in 62.5 percent of those repaired by homologous artery grafts. Lateral repair resulted in only 5.6 percent thrombosis.

Late Follow-up Studies

Since 62 of the 193 repairs in surviving patients had incomplete followup studies these are eliminated and only 131 cases in which there were late followup studies are reported (table 6). Counting the same 26 amputations reported in the short-term followed group and which remain unchanged for this group of 131 late followed patients, the amputation rate is increased to 19.8 percent.

An attempt to determine the exact number of thromboses has been difficult even in this followed group because it has not been possible to do an arteriogram on every patient. This is a difficult procedure at best, high in the upper extremity. The volume of the pulse distal to the repair site is not always indicative of the condition of the repair. At some levels, collateral vessels are quite adequate or develop quite rapidly. Even though some patients with a poor pulse have been shown by arteriogram to have a patent but constricted repair, all patients with a poor pulse or absence of pulse following surgery have been recorded in this report as thrombosed.

Thrombosis was reported as occurring in 19, or 18 percent, of the 105 surviving unamputated patients on whom we have late followup studies (table 6). Of the unamputated patients whose vessels were repaired by anastomosis, 13.9 percent thrombosed. Excluding the patient amputated, none with lateral repair were reported as thrombosed. In the 21 patients whose vessels were repaired by grafts, 14 autogenous vein grafts and 7 homologous artery grafts were used. In this group 35.7 percent of the vein grafts thrombosed, compared to 57.1 percent of the artery grafts. This percentage was not surprising from previous experience with homologous artery grafts but it was not expected that it would be as high with the autogenous vein grafts.

Table 6. Late Followup

*Major Vascular Repairs—Korea 1953**

Repair	Total—Number	No Amputation				Amputated		Died—Number
		Good		Thrombosed		Number	Percent	
		Number	Percent	Number	Percent			
Anastomosis	96	62	86.1	10	13.9	13	15.3	11
Vein graft	24	9	64.3	5	35.7	8	36.4	2
Artery graft	11	3	42.9	4	57.1	3	30.0	1
Lateral repair	8	6	100.0	0	------	1	14.3	1
Conservative	3	3	------	0	------	0	------	0
Release spasm	2	1	------	0	------	1	------	0
Remove thrombus	1	1	------	0	------	0	------	0
Ligation	4	1	------	0	------	0	------	3
Total	149	86	82.0	19	18.0	26	19.8	18

*Percentages exclude patients who underwent amputation or died.

Discussion

Admittedly, the Korean war offered many advantages over World War II relative to vascular repair. During its latter phase the front line was relatively stable. The surgical hospitals were within 6 to 12 miles of the front and we had ample air cover plus the advantage of more rapid helicopter evacuation. The expanded antibiotic armamentarium, availability of new vascular clamps, plus the experience gained in vascular surgery since World War II, all contributed to the success of vascular surgery in the Korean war. The Potts ductus and coarctation clamps contributed immensely to the success of the entire vascular surgery program.

Obviously, once an amputation was reported, the late followup concerning the patient's extremity was known. By far the highest percentage of amputations occurred at the initial installation and so were reported. While we have 26 amputations, or 20 percent, reported in 131 late followed surviving patients, this percentage is believed to be too high. When the 62 patients were lost to followup, and not counted in this percentage, all had viable limbs. If these cases are included and the 193 cases with limited studies with the same 26 amputations are considered, then the amputation rate is 13.5 percent. This rate is certain to be low because amputations have been recorded outside of the Korean Theater. The correct amputation rate for the entire series probably ranges between 13.5 percent and 19.8 percent or possibly near the mean of approximately 16.5 percent.

In order to present an accurate picture of the rate of thrombosis, findings of both the entire group of 193 patients with limited studies and the followed group of 131 patients have been presented. Ten thromboses are known to have existed in the 62 patients lost to followup. The number of thromboses in the amputated patients is unknown so the rate of thrombosis is figured for only the living unamputated patients. When rates of thrombosis of the short-term followed and late followed groups are compared, they are found to be almost identical (tables 5 and 6). If these findings are any criteria to the most satisfactory methods of repair, then the preferred methods are, in order, lateral repair, direct anastomosis, autogenous vein graft and homologous artery graft. However, it must be borne in mind that lateral repair was used for only the simplest lacerations and the more extensive the wound the more complicated the repair.

Lateral repair should be reserved for only minor, clean-cut lacerations of the artery. Large irregular lacerations are better excised with repair by direct anastomosis. By the same token, if the damage area of the vessel is large, it is often wiser to débride thoroughly and insert a graft rather than to sacrifice important collaterals in order to perform an anastomosis. An anastomosis under undue tension tends to separate or to create a spasm with resulting thrombosis.

Even though a number of limbs have come to amputations and others have been crippled by loss of muscle tissue or have complications of nerve injury or compound fractures, the salvage of limbs by repair of acute vascular injuries in Korea has been significant.

Summary

1. An attempt was made to follow every soldier with a major artery repaired in Korea during 1953. These findings are compared to findings reported from Korea during 1952.

2. During 1953 there were 211 major arterial repairs in 205 patients recorded from the Korean war. Death occurred in 15 patients with 18 repairs. Of the surviving patients, 26 required limb amputation.

3. Of the 193 repairs in surviving patients with short-term followup studies during 1953, amputation resulted in 13.5 percent. This is an improvement of 34.1 percent over an analogous series of 127 cases with 20.5 percent amputations reported from 1952.

4. Sixty-two of the 193 patients were lost to followup, leaving 131 with late followup studies of whom 26, or 19.8 percent, required amputation.

5. The correct amputation rate for the entire series ranges between 13.5 percent and 19.8 percent or possibly near the mean of approximately 16.5 percent.

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6. A comparison of the rates of thrombosis in repairs with short-term studies and those with late studies shows the findings to be almost identical. If absence of thrombosis is an indication of superior methods of repair, then in order of preference they are, lateral repair, direct anastomosis, autogenous vein graft and homologous artery graft. These results also correlate closely with the severity of the vascular wound.

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AN ANALYSIS OF FOLLOWUP STUDIES ON 115 ACUTE VASCULAR REPAIRS*

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The improved management of acute vascular injuries, established during the Korean conflict, represents one of the most outstanding achievements in the realm of war surgery. Although the incidence of amputation of a limb sustaining a major arterial interruption has been reduced from 49 to approximately 15 percent, this does not fully demonstrate the value of initial vascular repair. Many patients are now using a functionally adequate limb which, in former years would have been, at best, simply a viable limb. However, few methods of management, regardless of how physiologically conceived or technically performed, are entirely satisfactory and this is especially true when considering battle casualties and the problems associated with them.

During the period from August 1952 to December 1953 a total of 115 patients who had initial major arterial repairs performed in Korea were studied at this hospital. They represent only those patients who did not later require amputation of the involved extremity. All who required amputation, prior to evacuation from the Far East, have been previously reported and were excluded from this survey, our prime purpose being to evaluate the ultimate status of the vascular system in those patients who were considered successfully treated. To this extent, the findings are selective in nature but they do emphasize several important points. Probably their greatest value lies in the fact that they demonstrate that the results have not been perfect and much additional experimental and clinical investigation needs to be done.

Functional vascular surveys were performed on all patients and consisted of: (1) gross physical evaluation of the blood supply to the limb, (2) pulsations in the peripheral arteries, (3) oscillometric and skin temperature studies, (4) exercise tolerance tests, (5) arteriography and (6) visualization of the vascular repair if the limb was operated upon because of associated nerve or bone damage.

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In the great majority of patients, an adequate blood flow and a patent arterial repair could be ascertained by simple physical examination of the extremity and palpation of the peripheral pulses. On this basis, 87 patients were considered to have a functionally adequate circulation with a patent major arterial repair. Peripheral pulses were palpable in 93 patients but, in 6 of these, were markedly diminished and were believed due to collateral circulation. This was later substantiated by arteriography. In 5 patients peripheral pulsations, equal to those in the uninvolved extremity, were recorded. However, in each instance thrombosis of the major channel was demonstrated by further study. Despite this occlusion, the collateral circulation was extensive enough to prevent any evidence of arterial insufficiency. In 22 patients no peripheral pulses were demonstrated and each was proved later to have a thrombosis of the arterial repair. Thus, of 33 later proven thromboses, 22 had no peripheral pulses, 6 had markedly diminished pulses and 5 had excellent pulses. As would be expected from the known areas of greatest collateral circulation, of upper extremity occlusions which numbered 16, only 7 had no peripheral pulses, 5 had diminished pulses and 4 had excellent pulses. In the lower extremity, where the collateral circulation is much less adequate, entirely different results were observed. Of 17 patients with arterial occlusion, 15 had no pulses while only 1 each had diminished or excellent peripheral pulsations.

Oscillometric and skin temperature studies proved to be of little additional value in determining the adequacy of the circulation. With few exceptions the oscillometric readings corresponded closely to the palpable peripheral pulses. In several patients severely depressed readings were obtained in the presence of rather good peripheral pulses but in each instance the vascular repair was shown to be occluded. In almost all patients with patent arterial repairs, the readings from the affected limb were either equal or only slightly depressed as compared to the uninvolved extremity. The room temperature thermocouple studies, on the other hand, showed no correlation with the status of the major arterial channels.

An interesting observation was made in regard to the exercise tolerance tests. Several patients with patent arterial repairs were observed to have a paradoxical response to exercise, the oscillometric deflections decreasing rather than increasing. By arteriography, marked constriction was observed at the repair site. One might postulate that constriction and tension at the suture line acts as an irritating factor during exercise and results in reflex vasospasm with diminution of the arterial inflow. Such a factor might well counteract the value of the repair and eventually lead to thrombosis at that site. Similar instances have been observed in patients with arteriovenous fistulas repaired

under tension and with excessive constriction. If this conclusion be true, it would suggest the inadequacy of determining functional capacity on the basis of arteriography or tests performed at rest. It would also indicate the importance of avoiding any significant degree of tension or constriction at the suture line during performance of the vascular repair.

Arteriography was performed on the great majority of patients studied and proved to be the best method of evaluating the status of the repair. All injections were made percutaneously using either 70 percent Diodrast or Urokon as the contrast media. Eight roentgenograms were taken at 0.8 second intervals with the Sanchez-Perez rapid casette changer. Using this technic, demonstration of the arterial repair was excellent. It also permitted adequate visualization of the collateral circulation and the configuration of the distal main artery in those patients in whom thrombosis had developed.

Of the 115 patients studied, occlusions were found in 33 or 28.7 percent, a rate far higher than expected based on the results of several hundred vascular repairs performed in this hospital for other lesions. However, this figure loses some of its significance when it is remembered that not one patient in this entire series lost any part of a limb as a result of arterial damage. Since most patients who were shown to have a late thrombosis had good peripheral pulsations prior to evacuation from the Far East, it can be assumed that the repairs functioned at least long enough to preserve the viability of the limb.

Further analysis of this group of patients revealed a direct correlation, of statistical significance, between the type of repair performed and the occurrence of late thrombosis. Occlusion occurred in only 18.8 percent of direct anastomoses as compared to 44.4 percent of lateral repairs, 47.4 percent of autogenous vein grafts and 71.4 percent of homologous artery grafts. These figures are difficult to explain with the exception of the lateral repairs. Here, thrombosis was probably the result of inadequate arterial débridement and it was felt that this method of management should rarely, if ever, be used. The difference in thrombosis rate between the vein graft and the artery graft is not understood. In chronic vascular lesions as fistulas, aneurysms and segmental arterial blocks, either type of graft can be employed with equal success. It is fair to state, however, that from the results thus far obtained, the artery graft should not be employed in battle-injured arteries unless an adequate vein graft is not available.

Since an overall incidence of thrombosis of 28.7 percent was much higher than expected, an attempt was made to analyze the possible causes without respect to the type of repair performed. Several factors were uncovered but they failed to provide a cause in the majority of patients. In 21 or 63.6 percent of all patients with throm-

boses there was nothing found which could have explained the late failure of repair. In the remaining 12 or 36.4 percent a definite predisposing cause was found. Tension and constriction at the suture line was implicated in 15.2 percent (5 cases) of patients. Infection was responsible in 12.1 percent (4 cases); secondary hemorrhage in 6.1 percent (2 cases); and use of a damaged vein as a graft in 3 percent (1 case). From this it can be seen that all known causes were the result of technical errors which could have been prevented.

A study was then made of all patients with thromboses to see if there was any correlation with some of the factors which influence the initial repair. These factors are: (1) time lag, (2) wound size, (3) wound location and (4) associated bone and nerve damage. The results seem to indicate that time lag and wound size may be of some importance but in no instance was there any statistical correlation. The presence of an associated bone or nerve injury would appear to create a situation which would predispose to an increased incidence of thrombosis but again the figures did not substantiate this impression.

Finally, let us consider the functional results in the 33 patients who had occlusions. Sixteen occurred in the upper extremity. It has already been demonstrated that, because of the excellent collateral circulation that exists in this area, symptomatic arterial insufficiency was unusual. Only one patient required additional treatment, which consisted of a secondary repair of the artery using a vein graft. More serious problems were encountered in the 17 patients with thrombosed arterial repairs in the femoral and popliteal areas. Only 3 were asymptomatic and 2 of these had excellent distal pulses despite the major vascular occlusion present. Three other patients have not been completely evaluated because of associated injuries. The remaining 11 patients had definite symptoms of arterial insufficiency. In each instance a secondary vascular repair, employing a vein graft, was believed indicated. Two patients refused treatment and one had a thrombosis extending into the posterior tibial artery which precluded any attempt at arterial restoration. In 8 patients, or 72.7 percent of those with symptomatic insufficiency, the occluded segment of vessel was excised and the major channel restored by means of an autogenous saphenous vein graft. These varied from 14 to 32 centimeters in length. In each instance the symptoms of insufficiency were relieved and a functionally viable limb resulted.

Summary and Conclusions

1. One hundred fifteen patients, with arterial repairs performed in Korea who did not lose a limb, were studied at Walter Reed Army Hospital.

2. Complete organic and functional vascular surveys were performed on all patients.

3. Accurate physical examination was sufficient to determine the status of the vascular system in the majority of patients.

4. By arteriography, late thrombosis had occurred in 33 or 28.7 percent of patients but in no instance did this require amputation of a limb.

5. Thrombosis occurred in 18.8 percent of direct anastomoses, 44.4 percent of lateral repairs, 47.4 percent of autogenous vein grafts and 71.4 percent of homologous artery grafts.

6. In 63.6 percent of patients no cause for the thrombosis could be found.

7. The factors which could be implicated were, in the order of importance, tension and constriction at the suture line, infection, secondary hemorrhage, and use of a damaged vein as a graft.

8. Time lag, wound size, wound location and associated bone and nerve injury could not be correlated with the incidence of thrombosis.

9. Following thrombosis of the vascular repair, symptoms of insufficiency were almost entirely limited to patients with lesions in the lower extremity.

10. Eight patients, or 72.7 percent of those with symptoms of insufficiency, had arterial continuity restored by a secondary grafting procedure with excellent results.

11. The results of primary repair of battle-injured major arteries are not entirely satisfactory and much experimental and clinical investigation remains to be done.

THE EARLY MANAGEMENT OF GENITOURINARY WAR WOUNDS*

COLONEL JACK W. SCHWARTZ, MC

Introduction

As in other fields of surgery, morbidity and mortality rates in genitourinary war wounds during the Korean conflict showed a significant reduction from those of World War II. Of prime importance in accomplishing this has been the remarkable achievement of teamwork in integrating all echelons of the Army Medical Service. In this war the Mobile Army Surgical Hospital (MASH) came into its own, and for the first time in the history of warfare the wounded soldier could receive definitive major surgery within minutes of being injured, transportation in a large percentage of cases being effected by helicopter from as far forward as the battalion aid station.

Other factors which have favorably influenced wound management in Korea are: the development of a vast array of antibiotic drugs; improvements in anesthesia, shock control and blood vessel surgery; and the application of the artificial kidney and body armor.

Because of the high concentration of the broad-spectrum antibiotics in the urine, these drugs have been of particular benefit in the treatment of wounds of the urinary tract. Conservative renal surgery can be performed in some cases today in which conservatism would have been unthinkable a decade ago. The development of the highly skilled specialty of anesthesiology, improved anesthetic agents and the endotracheal tube have assisted the surgeon materially in lowering operative mortality rates by providing greater relaxation, shock control and longer safe operating time. The anesthesiologist has been a boon particularly to the thoracic surgeon, and incidentally to the urologist because of the frequent concomitance of thoracic and renal wounds. In the control of shock the use of whole blood in Korea largely displaced the use of plasma and the plasma extenders. Toward the end of the conflict whole blood was being brought by ambulance or helicopter and used as far forward as the battalion aid station. Administration of blood during transportation of the casualty was a common practice. However, the early enthusiasm for intra-

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arterial transfusion has largely waned; it is questionable whether it has any advantage over intravenous administration.

Although the many contributions in blood vessel surgery made in Korea by the Surgical Research Unit have as yet had little application to traumatic urology, opportunities exist for future treatment of renal vascular injuries. The use of hemodialysis and body armor are mentioned later.

Incidence

Information obtained from the Medical Statistical Division of the Office of The Surgeon General reveals that "final tabulation of medical statistical data for World War II and Korea have not yet been completed and none are available in sufficient detail of cross-tabulation to furnish total U. S. Army battle injuries and wounds by detailed anatomical location, in particular wounds or injuries involving the genitourinary organs." Partial data, however, are available for World War II up until June 1944, and for the Korean conflict from July 1950 through December 1952. On the basis of these preliminary tabulations, it is determined that genitourinary casualties represented 0.5 percent of all World War II casualties and 0.65 percent of Korean casualties. These figures were further broken down to reveal the following percentages: World War II—kidney, 25 percent; ureter, 1 percent; bladder, 15 percent; external genitalia, 56 percent; whereas the following incidence occurred in Korea—kidney, 22 percent; ureter, 1 percent; bladder, 12 percent; external genitalia, 59 percent.

It is known that of 8,000 consecutive casualties admitted to Tokyo Army Hospital, 1 percent demonstrated urological wounds.

Marshall, reporting on urological casualties in the European Theater of Operations, stated that battle casualties accounted for 93.3 percent, whereas 6.3 percent were due to motor accidents, falls, blast injuries, etc.

Interesting statistics compiled by the Second Auxiliary Surgical Group, 1942–45, and reported by Beebe and DeBakey, reveal the marked rise in mortality rates when multiple organs are injured. With single organs involved, they report the following mortality percentages in urinary tract wounds: kidney, 16; bladder, 0; ureter, 0. If complicated by trauma to other viscera, these percentages rise to: kidney, 38; bladder, 34; ureter, 42.

General Considerations

War wounds are, in the main, "open" wounds and result from gunshot missiles or shell fragments. It is this type of wound that is of primary concern to the military surgeon at present. Unconventional

weapons of the future may alter the type of casualty the military surgeon will be called upon to treat.

Open wounds of the urinary tract are frequently associated with wounds of other organs which are more serious and of greater urgency. Penetrating wounds of the abdomen or chest must of necessity, as a rule, take priority in treatment. Because of the magnitude of associated wounds, injury to the urinary tract may be overlooked.

Injury to the kidney, ureter or bladder may be suspected from the course of the missile. Free fluid in the abdomen should make one suspicious of urinary extravasation into the peritoneal cavity. The urine of the wounded patient should always be examined, even if catheterization is required to obtain a specimen. The presence of gross hematuria indicates injury to some level of the urinary tract. The degree of hematuria is no criterion of the extent of injury; for example, in severance of the renal vessels or ureter, hematuria may be absent.

Urinary extravasation is a serious complication and if it occurs in a closed wound prompt drainage is imperative. Frequently the missile tract provides a sinus through which adequate drainage occurs and the hazard is lessened. Extravasation into the abdominal cavity may occur from an intraperitoneal rupture of the bladder, or through perforation of the posterior parietal peritoneum associated with ureteral or renal injury.

The usual diagnostic urological procedures, namely, excretory urography, cystoscopy, cystography and ureteral catheterization, as a rule have no place in the management of the severely wounded casualty. The decision to operate must be made on physical signs. While early operative intervention is definitive in that it is life-saving, it is not necessarily curative, and secondary procedures may be required later at fixed hospitals where the whole diagnostic armamentarium may be used to good advantage.

The surgical approach is influenced by involvement of associated organs. The conventional lumbar incision should be used only if it is certain that the injury is limited to the kidney or ureter. Otherwise, the abdominal or thoraco-abdominal approach is indicated. In the abdominal exploration of any war casualty the surgery is not complete without an inspection of the posterior parietal peritoneum.

Proximal urinary diversion is a well established principle in the repair of a wound of the urinary tract. This is accomplished by nephrostomy, pyelostomy, ureterostomy or cystostomy, depending on the site and extent of the lesion.

Renal Injuries

Wounds of the kidney are relatively uncommon in combat. In World War II only 0.1 percent of combat casualties suffered wounds

limited to the kidney. Information obtained from the Office of The Surgeon General reveals that in World War II, 10 percent of chest wounds and 6 percent of abdominal wounds were complicated by renal injury. For Korea it is estimated that 8 percent of chest wounds and 7 percent of abdominal wounds were similarly complicated. Conversely, in open renal wounds in warfare approximately 70 percent are complicated by injury to adjacent abdominal or thoracic viscera. Approximately 25 percent of all genitourinary tract injuries involve the kidney.

The extent of renal trauma varies in severity from contusions with subcapsular rupture to extensive lacerations, pulpification and infarction of parenchyma, tears into the renal pelvis and major injury to the renal vessels. Hematuria, pain, tumor and shock are present to a greater or lesser degree in all cases. However, these signs may be masked by the severity of associated injuries.

The emergency treatment of open renal wounds is directed toward controlling hemorrhage and providing drainage. The principle of treatment should be conservatism and only irretrievably damaged kidneys should be removed. That this principle of conservatism was practiced in World War II is indicated by the report of only 54 primary nephrectomies in a total of 205 cases of renal injury (Clarke and Leadbetter). Primary nephrectomy should be reserved for massive or uncontrollable hemorrhage or urinary extravasation, extensive destruction and infarction, severe infection and secondary hemorrhage.

Improvements in anesthesia, blood replacement and antibiotics have permitted greater conservatism in renal surgery. Bleeding may be controlled by packing, or better still by suture of the parenchyma over fat pads. The chemical hemostatic agents are not favored because they encourage infection. In polar injuries, segmental resection only is indicated, the open margin being closed with figure-of-8 or mattress sutures over a fat or muscle pad. Nephrostomy drainage should be provided in all severe injuries to the kidney. All retroperitoneal tubes and drains should be delivered to the exterior through a stab wound in the flank. Improvement in vascular surgery developed in the Korean war makes repair of wounds of the renal vascular pedicle feasible; however, there has yet been no report of the successful employment of this procedure in war casualties.

A small percentage of late secondary nephrectomies will be required because of infection, hydronephrosis, atrophy, stone formation, persistent urinary fistula and hypertension. This late surgery has no place in the combat zone. In no instance should a kidney be removed without prior determination of the presence and condition of the opposite organ.

Ureteral Injuries

Because of the deep and protected position of the ureters, injury to these structures is uncommon. Kimbrough reported 8 cases of ureteral damage in 235 genitourinary tract injuries in World War II. A total of only 35 cases has been collected from all casualties in World War II. Lieutenant Colonel Carl W. Hughes, MC, collected 7 cases of ureteral injury in 448 wounds of the abdominal organs in 291 patients admitted to a MASH in Korea.

Less than 20 percent of wounds of the ureter are recognized at the time of injury or initial surgery. Urinary leakage in an open wound may be the first indication of ureteral injury, the fistula developing days or weeks after the initial trauma. Damage to the ureter should be suspected if the wound of entrance or exit is in the flank, or if a retroperitoneal hematoma is discovered at the time of any abdominal exploration.

Initial repair of the ureteral injury is highly desirable. Delay in repair frequently results in scar formation with obstruction and hydronephrosis necessitating a later nephrectomy. Rarely, a minor wound of the ureter will heal spontaneously. Occasionally, healing will occur merely by inserting an inlying ureteral catheter. As a rule, however, surgical intervention is required. If the ureter has been transected, end-to-end anastomosis with interrupted catgut sutures incorporating only the adventitia is the treatment of choice. The ends of the severed ureter should be cut obliquely to lessen the chance of stricture formation. A splinting tube, preferably polyethylene, should be left indwelling for 3 weeks. Small rents or lacerations of the ureter can be treated with ureteral intubation, omitting the sutures, as advocated by D. M. Davis. Recent evidence indicates that an avulsed small segment of ureter will bridge an indwelling splinting tube even though the ends cannot be approximated, all layers of the ureter being completely regenerated in approximately 6 weeks. Except in the mildest trauma, proximal urinary diversion should be provided. The use of a T-tube inserted through a proximal ureterotomy, the lower limb splinting the suture line, offers both intubation and drainage. In the event that a large segment of ureter has been avulsed or primary repair is not feasible for other reasons, the proximal segment should be exteriorized and reparative surgery deferred.

Ureteral injury near the bladder is difficult to recognize because of the presence of the associated hematoma. If the patient's condition is good and the distal ureter is suspected of involvement, the bladder may be opened and the orifice catheterized to determine the integrity of the ureter. If severed, a primary ureteroneocystostomy is the operation of choice.

In all cases of ureteral injury or suspected injury the retroperitoneal space should be drained through a small stab wound in the flank. Because of the frequency of stricture formation following ureteral injury, the ureter should be calibrated a few weeks after surgery. Periodic dilatations may be required in rear area hospitals.

Bladder Injuries

In Kimbrough's series, 15 percent of all genitourinary tract wounds involved the bladder. In 70 percent of the 315 bladder wounds collected by Clarke and Leadbetter, there were concomitant wounds of the rectum, large or small bowel. Injury to the bony pelvis was common. Intraperitoneal or combined extra- and intraperitoneal perforations occurred in 83 percent of bladder wounds. With the incorporation of the female soldier into our Armed Forces injuries to the internal female genitalia may add further complications.

Bladder injury should be suspected in all penetrating wounds of the lower abdomen, buttocks and adjacent regions. Leakage of urine through the wound is positive evidence of perforation. Hematuria, tenesmus and inability to void are presumptive symptoms. A fluctuant mass may be palpable to the examining finger on rectal examination. Cystoscopy, which adds shock to the already wounded patient, is unnecessary and usually contraindicated. Withdrawal of an injected measured amount of fluid into the bladder through a urethral catheter may be a dangerous procedure and is diagnostically fallible.

Immediate exploration is indicated if the diagnosis is in doubt. Ordinarily this is performed at the evacuation hospital unless associated wound require treatment at the Mobile Army Surgical Hospital.

In intraperitoneal rupture the peritoneal cavity should first be evacuated of blood and urine. The bowel should be examined for injury. The bladder perforation should be repaired from the peritoneal aspect and the peritoneal cavity closed without drainage. The bladder is then exposed extraperitoneally and cystostomy drainage provided, the drainage tube being placed high in the fundus of the bladder and brought out along an oblique tract to aid subsequent healing. Prognosis is much poorer in intraperitoneal perforation.

In extraperitoneal perforation, the bladder should be opened and inspected. It should be remembered that both a wound of entrance and a wound of exit may be present. If possible, the laceration should be sutured from the outer aspect of the bladder. If this is not easily accomplished intravesical closure may be done. If the wounds are small, closure is not essential. Cystostomy drainage, however, should always be provided. The perivesical spaces should be well drained

with Penrose drains placed deep into the pelvis on either side of the bladder, as well as into the prevesical space.

In combined rectal and vesical wounds, in addition to repair of the bladder, a colostomy is indicated. Additional drainage must also be provided through a perineal incision with insertion of drains into the ischiorectal fossae and the retrorectal space.

Wounds of Urethra and External Genitalia

These comprised 59 percent of all genitourinary tract injuries in the first 8,000 Korean war casualties admitted to Tokyo Army Hospital. In World War II, Kimbrough reported 68 percent incidence in 235 genitourinary casualties and Culp, 50 percent in 160 cases. Land mines contribute a large part in the high incidence of this type of casualty.

Urethral bleeding, urinary retention and extravasation are the signs and symptoms of urethral injury. The extravasation occurs within Colle's fascia if the injury is distal to the triangular ligament and into the perivesical and retroperitoneal spaces if proximal to the triangular ligament.

The principles of treatment in urethral injury consist of: (1) urinary diversion by cystostomy, and (2) reestablishment of the continuity of the urethra. End-to-end suture of the severed urethra should accomplished over an indwelling catheter where possible. If the urethra is not completely divided, insertion of a splinting urethral catheter is usually adequate. If difficulty is encountered in passing the catheter or locating the severed ends, this can usually be overcome by the use of interlocking sounds, one passed through the penile urethra and the other downward through the opened bladder. If a segment of urethra has been avulsed, prohibiting the approximation of the severed ends, an indwelling catheter bridging the gap and left in place 8 weeks will permit regeneration of the urethra over the splint. Every effort should be made to repair the urethra at the initial surgery, as delay results in extensive scar formation and jeopardizes a satisfactory end result.

Where the emembranous urethra has been torn loose from the triangular ligament, as frequently occurs by shearing action in pelvis fractures, a Foley catheter should be introduced into the bladder with the interlocking sounds and traction applied to the catheter to pull the bladder neck down. In the exceptional case, suture of the divided urethra can be accomplished through perineal exposure, but as a rule associated perineal injury prohibits this procedure.

As in bladder wounds, wounds of the urethra associated with large bowel injury must be treated also with a proximal colostomy. Recto-urethral fistulae are fairly common in these wounds and their repair

is a function of Zone of Interior hospitals. The method of Young and Stone of advancement of the rectum in the treatment of recto-urethral fistulae gives good results. Lewis utilized this operation successfully in 13 cases.

Wounds of the external genitalia should be treated with the utmost conservatism. Because of the excellence of the blood supply of these organs, tremendous regeneration can occur. Trauma to the urethra is frequently associated with lacerations of the corpora, and results in deformity of the penis. Tears in Buck's fascia should be sutured and the shaft bandaged over an indwelling urethral catheter to control hemorrhage, but being careful to avoid constriction. Van Buskirk reported one case of denudation of the penis in a Korean casualty treated by burying the organ in a scrotal tunnel.

More than 50 percent of external genital wounds involve the testes. Every attempt should be made to conserve these traumatized organs, unless the blood supply is hopelessly lost. Lacerations of the testicle should be treated by débridement and suture of the tunica albuginea to prevent herniation of the spermatogenic tissue. In avulsion of the scrotum, the testes should be placed under the skin of the inner aspects of the proximal thighs.

The Neurogenic Bladder

In World War I, 60 percent of patients who sustained spinal cord injuries died of urinary tract infections. With better understanding of bladder physiology and the urological management of the neurogenic bladder, the mortality of spinal cord injuries has been reduced to about 15 percent.

Spinal cord injury, regardless of the level or extent of the lesion, results in a temporary period of "spinal shock" below the level of the lesion. During this period the detrusor muscle is devoid of sensation and reflex activity but retains its inherent tone. The period of "spinal shock" which may last from a few hours to many months is critical from the standpoint of preserving bladder tone. If permitted to distend and overflow, the bladder eventually decompensates, becomes anoxic, infected and fibrotic and eventual functional return cannot occur even though the nerve injury may be relatively trivial.

Bladder tone may be preserved by providing drainage as soon as a diagnosis of neurogenic bladder is made. The urethral catheter should be inserted in the most forward medical installation in the chain of evacuation. A small catheter, 16F to 18F, preferably Foley type, should be used. A larger caliber is apt to cause infection and trophic ulceration of the urethra. Intolerance to the catheter, manifested by excess purulent urethral discharge, periurethral abscess of

epididymitis, is indication for suprapubic cystostomy. If the patient tolerates the catheter well it may be left indefinitely, being changed only as often as is necessary to prevent incrustation and urethritis. Spontaneous overflow or intermittent catheterization should *never* be used in the treatment of the neurogenic bladder. A closed system of drainage should be attached to the indwelling catheter. Irrigation with Subey's "G" or similar solution, by tidal or manual method, incorporated in the drainage system, acts to prevent incrustations and bladder stones.

The ultimate functioning pattern of the stabilized neurogenic bladder will depend on the level and extent of the cord or brain lesion. Rehabilitation of the paraplegic is a function of Zone of Interior medical installations. The Veterans Administration is now charged with this responsibility following initial stabilization of the patient in military hospitals.

Artificial Kidney

The Renal Insufficiency Center of the Surgical Research Team, under command of Major William H. Meroney, MC, was assigned to Korea for the last 1½ years of the Korean conflict for the evaluation of hemodialysis in the treatment of acute renal failure associated with war injury. Approximately 150 patients were treated by this unit with results which were encouraging and even definitely lifesaving in several instances, although the results were difficult to evaluate in most cases because of the severity of associated trauma. Hollingsworth Smith, at a committee meeting of the National Research Council in Washington, D. C. (18 March 1953), reported that the mortality rate of severely wounded anuric soldiers in Korea was reduced from approximately 90 percent to 60 percent when an artificial kidney was employed behind the front lines. Because of the small numbers involved these figures can hardly be considered statistically significant.

Hemodialysis is not a substitute but an adjunct to the intelligent management of renal failure. There are few dangers to its use when employed by a skillful team. Active bleeding remains the only real contraindication to dialysis. Heparinization in these individuals may result in a fatal hemorrhage.

The artificial kidney promises great usefulness in the treatment of war casualties. Because of the relative infrequency for its need and the highly trained staff required for its employment, it is believed that only one artificial kidney per Theater of Operations would be sufficient provided transportation facilities were adequate.

Body Armor

All combat troops of the Eighth U. S. Army were eventually supplied with body armor. The first trials were begun in June 1951, but more extensive tests were not started until March 1952. The type of body armor generally issued was the thoraco-abdominal vest made of nylon. Some use was made, on a much more limited scale, of armored shorts.

Evaluation of the protection afforded by body armor has not been completed. Information obtained from the Office of The Surgeon General states: "Although data are not presently available to this division which measure the efficiency of body armor with respect to particular sites, it is generally believed that the absolute incidence of wounds of the kidney would be reduced by the general use of body armor of the nylon vest type." Because more than half of all genitourinary wounds occur to the external genitalia, the urologist would favor the use of protective armor covering this area.

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PRACTICAL CONSIDERATIONS IN THE TREATMENT OF EYE CASUALTIES*

Major John E. Edwards, MC

Injuries of the eye have always posed a difficult problem for the general medical officers who have to deal with them in forward echelons. In this discussion I shall present what we have found in Korea to be the most satisfactory methods of handling these casualties, both from the medical and the military standpoints.

The seriousness of the problem is mainly due to the severity of the injuries and their likelihood to result in permanent and grave disabilities. The number of eye casualties has been only about 5 percent of the total injured in both World Wars and Korea, but in Korea alone, 1,071 soldiers suffered blindness in one and 149 in both eyes.

Tiny particles will cause little damage to other parts of the body, but their penetration into the eye is often enough to destroy its usefulness. The eyes of an infantry man have to be kept under protective cover much of the time, both in offense and in defense. The skull above them is protected against small missiles by the helmet, but the eyes' only protection is their location in the bony orbit and the winking reflex of the lids which is not effective against the high-speed particles of modern warfare.

The injuries of the eye principally encountered are: (1) burns, (2) contusions, (3) abrasions, (4) penetrating wounds.

1. *Burns.* First let us consider burns. They are (a) chemical or (b) thermal.

a. Chemical. In Korea the most frequent offenders were battery acids, lye used in cleaning solutions, and brake fluid (fig. 1). The damage done by chemical agents depends not only on the amount and concentration but also on the length of time in which they are able to act. This is particularly true of alkalis where the end product, in itself, is strongly alkaline. It is, therefore, imperative that all chemicals spilled in the eye be washed out immediately with whatever water may be available. It happens, unfortunately, all too often that patients are brought in to medical installations several minutes away without the eye having been washed out, and with dire results, al-

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FIGURE 1.

though local source of water was available. This indoctrination should be done in basic training and repeated as often as may be necessary. The pain which occurs with burns and with trauma in general is in a large part due to a reflex spasm of the ciliary bodies and the iris which can be relieved by the use of mydriatic drugs such as homatropine, scopolamine and atropine. These drugs should be used along with local antibiotic agents of which sulfacetamide and bacitracin ointments are the safest and most effective.

A special type of burn is due to phosphorus. In this, the treatment consists of thorough débridement of all phosphorus particles and neutralization of any remaining fragments with copper sulfate. Two percent copper sulfate is used, then washed out with saline. The hazards of copper sulfate are well recognized, yet the penalty for failure to remove all phosphorus is too great, and this justifies the rather heroic treatment. Again, as in any other type of burns, the use of mydriatics is advisable.

b. Thermal. Thermal burns of the eyeball itself are fortunately seldom serious because of the excellent protective mechanism provided by the closing of the lids. Third degree burns of the lids, however, are very disfiguring and disabling if not properly cared for. This is due to the contracting scars separating or everting the lids (fig. 2). This lack of protection to the eye may ultimately result in drying, then infection with loss of sight or even loss of the entire eye. Therefore, it is emphasized that even small third degree or questionable third de-

FIGURE 2.

gree burns of the eyelid be treated by prompt tarsorrhaphy. This should be accomplished as early as possible and certainly within the first 72 hours even at installations not giving definitive eye care. As a temporary measure, a simple suture connecting the marginal surfaces of the lids will suffice. This can be improved upon by making a shallow incision in each lid in the gray line which lies between the row of lashes and the openings of the Meibomian glands and suturing the marginal

surfaces together. The resulting scar tissue will yield a firm closure which can later be released with ease.

2. *Contusions.* Contusions encountered in Korea came from two sources: from accidental injuries such as those caused by fists, automobile accidents and rifle barrels, and from combat injuries such as those from mines, concussion grenades or other exploding missiles.

Contusions can vary in severity from a black-eye to rupture of the eyeball. In severe contusions there is usually edema of the conjuctiva and cornea, and blood in the anterior chamber (fig. 3). With this there is often edema of the retina manifested by a great increase in shiny light reflexes. All but the most minor contusions should be treated by binocular bandages and evacuation as litter patients to an ophthalmologist because of internal hemorrhages and the ever-present danger of retinal detachment. In this latter condition, the retina separates from the underlying choroid from which it receives nourishment. The detached portion dies within a few days to few weeks if it is not re-attached by absolute bed rest and surgery. The surgery consists of electrocoagulation through the sclera with production of scar tissue. In Korea we encountered five patients with retinal detachment. Mydriatics should be avoided in contusions particularly in the presence of intraocular hemorrhages as they occasionally result in delayed massive hemorrhages.

3. *Abrasions.* The most common cause for abrasions was brushing against branches of trees and shrubs and accidentally scratching with fingernails. One patient's eye, however, was abraded by a missile, 10

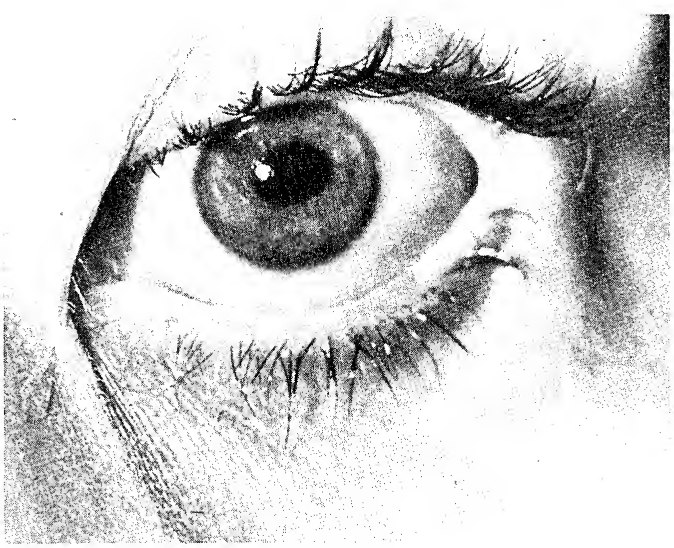

FIGURE 3.

x 12 x 12 mm. in size, which skimmed the cornea and imbedded itself into the nose. The treatment of abrasions should consist of placing the eye at rest with aid of binocular bandages, mydriatics and antibiotics. The local antibiotic of choice again is sulfacetamide or bacitracin.

4. *Penetrating Wounds.* Penetrating wounds comprise the largest and most serious group. The causative agents are shown in table 1.

Table 1. Causative Agents

	Number	Percent		Number	Percent
High explosives	140	49	Accidental injuries:		
Mine	34	12	Weapons	26	9
Hand grenades	31	11	Industrial	38	13
Small arms	13	4.5			
Trip flare	4	1.5	Total	286	100

The simplest type are the superficial conjunctival and corneal foreign bodies. With care and a few simple instruments, these can be removed by general medical officers. Examination is best done by using oblique illumination, even with a good flashlight. The upper lid can be everted by having the patient look down, grasping the eyelashes and pulling them forward, then pressing the skin above the tarsus downward. Foreign bodies of the conjunctiva can be removed with a cotton-tipped applicator stick.

Foreign bodies of the cornea require pontocaine (½ percent) anesthetic, a fine-tipped Bard-Parker blade or a hypodermic needle and a magnifying lens or a loupe. The tip of the knife is placed beneath the edge of the foreign body and it is flicked upward. This is repeated until the particle is lifted out. When a foreign body has been in the eye for many hours, there is apt to be a rust-colored ring around it. This tissue reaction is also irritating and it is removed by the same way as the foreign body itself. Removal must be followed by antibiotic ointment such as sulfacetamide or bacitracin and mydriatics, preferably 0.25 percent scopolamine. Atropine effect lasts 1 to 3 weeks resulting in too prolonged interference with visual efficiency; therefore, it has no place in treating minor injuries. Carelessness and excessive manipulation, such as repeated attempts with cotton swabs, sometimes result in infection as shown in figure 4, with grave damage to the eye. The prolonged use of anesthetic ointments should be avoided as they inhibit healing and enhance the progress of infection by paralyzing the corneal nerves.

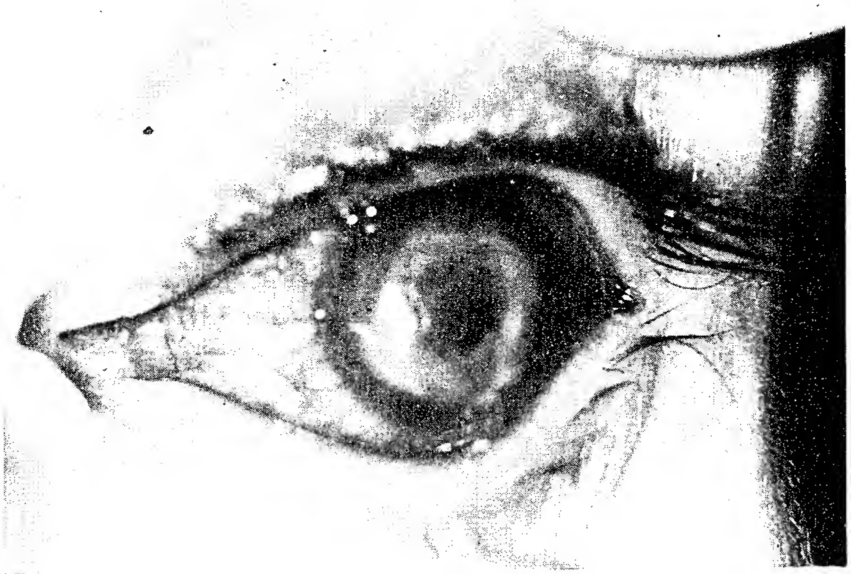

FIGURE 4.

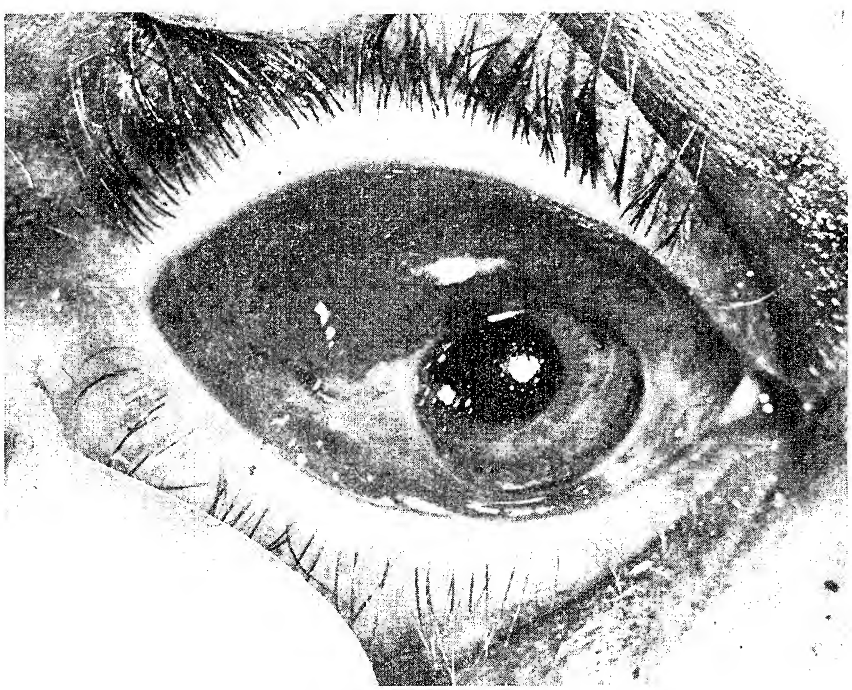

FIGURE 5

Injuries of a more major nature may be injuries of the anterior segment (fig. 5), wounds of the cornea with and without involvement of the iris and lens, or those of the posterior segment involving wounds through the sclera into the vitreous. In these, the wound of entry is often not evident, but posterior segment injuries should always be suspected in injuries of the lid. Deep anterior chamber usually denotes severe injury. With high-speed missiles, total fragmentation of the eye is often encountered. In some of these, such as seen in figure 6, one has considerable difficulty in finding the various

FIGURE 6

portions of the globe. Enucleation of such eyes can be made easier by first suturing the fragments together for traction and identification.

In all these injuries, the presence of foreign bodies must be suspected. The eye is capable of withstanding some of these foreign bodies for prolonged periods of time; others, especially copper-containing bodies, will produce rapid and inevitable degeneration of the eye.

The responsibility for giving definitive care for these major wounds must rest with the opthalmologist, as other physicians rarely have the necessary instruments or experience. The treatment must begin as soon as possible. The physiology of the eye depends greatly on maintenance of normal intraocular tension; therefore, early restoration of tension is of greatest importance. Certain other processes such as formation of adhesions will also be minimized by early definitive treatment. For this reason, early evacuation should be the principle at forward echelons. In order to place the eye at rest, both eyes should be bandaged and the patient should be evacuated by litter. Mydriatics should not be used in these wounds because of occasional complications of hemorrhage and anterior synechiae. Antibiotics such as penicillin and streptomycin, however, should be used liberally, as well as morphine and tetanus booster.

The principle of treatment by the ophthalmologist is to repair primarily any eye in which there has not been too great loss of intraocular contents. Many eyes which at the operating table were thought to be hopelessly lost ultimately recovered some sight. Surgeons who know the technic of enucleations but are not experienced in repair of eye wounds are likely to be tempted to enucleate eyes which could be repaired by an ophthalmologist. Conservative surgery is especially important in bilateral injuries.

During my 16 months of service in Korea we performed the following major operations on casualties:

Repair, wounds of sclera	110	319=70 percent
Repair, wounds of cornea	116	
Removal, F. B., vitreous	76	
Removal, F. B., anterior chamber	17	
Enucleation	129	
Eviscerations	4	
Lid repair (major)	68	
Detachment of retina	5	
Others	4	
Total	529	

Accurate localization of foreign bodies is of utmost importance and depends on competent use of x-rays. In the presence of various types of injuries and because of the patients' general condition, movements must be kept at a minimum in order to obtain good x-rays.

It has been the general experience that x-rays taken at forward installations rarely gave the opthalmologist all the information necessary, resulting in the necessity of exposing the patient to double manipulation. It is therefore most strongly advised that x-rays should not be taken at forward installations for localization, but only at the place of definitive treatment.

We had considerable success with stereo x-rays in localizing foreign bodies. The various more accurate methods of localization commonly used in the United States were not very feasible because of the variability of the power supply, the x-ray equipment, the poor cooperation of the patients and the presence of open wounds of the eye.

The stereo technic is also particularly suited to localization of multiple foreign bodies which are apt to be very confusing to other views. The routine view was the stereo-Waters view; i. e., chin and nose on the plate. For stereoscope, two prisms from an eye trial lens set were mounted to tongue depressors which yielded excellent stereopsis.

Complications. Endophthalmitis occurred in 25 out of 286 eyes; 10 of these, or 40 percent, were due to mine injuries (table 2).

Table 2. Endophthalmitis

	Number	Percent of injuries		Number	Percent of injuries
High explosives	7	5	Steel chip, hammer	1	------
Mine	10	29	Unknown	3	------
Hand grenade	2	7			
Small arms	1	------	Total	25	9
Stone	1	------			

Sympathetic ophthalmia, fortunately, does not pose the same problem that was encountered in the Civil War and the Spanish-American War. These instances were reduced to about 30 cases in both sides of the entire First World War, very few in the Second World War and I have not yet heard of one in Korea. With the advent of cortisone and with prolonged competent observation, eyes do not have to be primarily sacrificed because of possibility of sympathetic ophthalmia.

Military Aspects. During the Second World War, there was a relative shortage of ophthalmologists and as lateral evacuation was rarely possible, ophthalmologists could be assigned to base hospitals only. Furthermore, they had to contend with the slowness of evacuation. Nonetheless, they found that patients fared better if definitive surgery was not done by general surgeons in forward areas but by ophthalmologists farther in the rear. In Korea the situation was different: The

area was smaller, the lines of evacuation congregated at a more forward point which was relatively safe from attack, and both rapid and lateral evacuations were made possible by helicopters and Air Force evacuation planes. The type of injuries was also different as the mine and grenade wounds were well contaminated with the human manure from the rice paddies, which necessitated earlier débridement.

At the beginning of the war, definitive surgery was done mostly at Tokyo Army Hospital and some at a hospital ship in Pusan. The time elapsed between injury and arrival at Tokyo was often in excess of 24 hours. We found that the patients operated on by an ophthalmologist aboard the ship arrived in better condition at Tokyo than those who came directly, thus indicating the need for earlier surgery. For this reason, ophthalmologists were pushed forward into evacuation hospitals in Korea. Thereafter, definitive treatment could be given in 6 to 18 hours from even the most distant portions of the front line. In the opinion of everyone, the end-results justified this system.

Thus, in the light of the experience in both wars, it is recommended that ophthalmologists be placed as far forward as possible, depending on their availability, to enable preoperative time lags of less than 12 to 18 hours.

Concomitant Injuries. Attention is invited particularly to the 32 eye injuries which were seen in conjunction with neurosurgical injuries and to the 47 with maxillofacial wounds (table 3).

Table 3. Concomitant Injuries

	Number	Percent		Number	Percent
Surgical of face	42	14	Extremities	48	17
Maxillofacial	47	17	None	59	21
Neurosurgical	32	11	Unknown	49	17
Thorax	6	2			
Abdomen	3	1	Total	286	100

As these injuries also require specially trained and equipped personnel, this high proportion of coexisting wounds points to the advisability of placing an ophthalmologist, a maxillofacial surgeon and neurosurgeons in the same hospital.

In Korea this was achieved by the addition of a neurosurgical team to an evacuation hospital. Later, however, this excellent arrangement was disrupted and the neurosurgical team was moved forward to a MASH, 40 minutes helicopter travel time away. This entailed frequent trips to the MASH to operate on combined casualties. Except for the fortunate coincidence that the ENT surgeon was also a trained ophthalmologist, this system would have resulted in serious damage.

When a second neurosurgical team was sent to the east coast, an ophthalmologist was sent with them. In view of the great number of combined injuries, ophthalmologists should be placed in hospitals providing treatment of all wounds, including neurosurgical and maxillofacial injuries.

The advice of consultants was given great weight in matters of assigning personnel as well as of maintaining high caliber of medical care. This system worked out very well in Korea and it should be continued in the future.

The number of ophthalmologists needed in combat is one Board-qualified or Board-certified man and one slightly lesser trained man for each two corps. These lesser trained men, however, must spend some time with an ophthalmologist who is experienced in traumatic surgery prior to being assigned to a hospital of their own. This estimate, however, assumes good evacuation facilities.

The equipment available to ophthalmologists in Korea was greatly dependent on resourcefulness of the ophthalmologist and on the power given the Far East Consultant in recommending supplies. In many instances we were hampered by lack of equipment and at times found sorely needed equipment in hospitals lacking ophthalmologists. These difficulties can be avoided in another conflict by issuing to each qualified ophthalmologist his own equipment. A compact kit is currently being developed by the Ophthalmic Research Unit at Walter Reed Army Hospital.

Prevention. When one observes these casualties, one is struck by the large number of eyes lost because of tiny missiles. I also had the privilege of seeing soldiers whose eyes were protected by their glasses when their face was peppered by small particles. I feel that commercial safety glasses will protect against almost all fragments, 1 x 1 x 2 mm. in size and many of 2 x 2 x 2 mm., depending on the velocity, angle of impact, etc. You will note in table 4 that 115 out of 218 missile wounds, or 53 percent, would definitely have been prevented and 143 out of 218, or 66 percent, probably prevented by commercial safety glasses.

Table 4. Small Missile Wounds Causing Loss of Eyes

Size of missiles	Number	Percent	Size of missiles	Number	Percent
Less than 1 x 1 x 2 mm.	115	53	None	22	------
Less than 2 x 2 x 2 mm.	28	13	Unknown	46	------
Less than 5 x 5 x 5 mm.	26	12			
Over 5 x 5 x 5 mm.	49	22	Total	286	
Subtotal	218	100			

It is impossible to prevent all wounds, except by heavy steel goggles. As these are hot and restrict the field of vision, they would be totally unacceptable to the troops. Safety glasses, however, like body armor, would soon find acceptance.

Glasses were provided by having a refractionist and an optician with each division issuing 80 to 120 glasses a month. At corps level there was an optical repair truck which supplied 1,000 to 1,400 pairs of glasses per month and there was a base depot at Pusan. At the 121st Evacuation Hospital, an optometrist and I refracted the eyes of 500 to 700 soldiers per month. This system enabled a 24-hour service on almost all glasses. It is most advantageous to have such a system of procurement in forward echelons as this minimized time lost from the organizations. Although the prescription for glasses is supposed to be recorded on the immunization records, these were often not available to the optician or did not contain the prescription.

Summary

In summary, the Korean conflict taught us the following important lessons regarding care of eye casualties:

1. Definitive care should be done by an ophthalmologist.
2. Early evacuation is necessary with both eyes bandaged and on a litter.
3. Ophthalmologists should be assigned to hospitals to which patients arrive in less than 12 to 18 hours after injury.
4. Such hospitals should also have an ENT surgeon and neurosurgeons in addition to the usual complement of general surgeons and orthopedists.
5. Each ophthalmologist should be supplied with his own instruments.
6. Safety glasses should be issued to all troops in combat.

DISCUSSION—EYE CASUALTIES IN KOREA*

COLONEL J. H. KING, JR., MC

You have just heard an excellent though brief first-hand account of the management of eye casualties in Korea. The fact that many eyes were saved and much total blindness was prevented attests to the soundness of the principles of treatment which were outlined for you today. My experience in treating these patients from Korea begins farther back in the chain of evacuation—at Tripler Army Hospital in Honolulu—and at the final point of evacuation for many, the eye center here at Walter Reed Army Hospital.

Major Edwards has summarized the important lessons which were learned in Korea regarding the care of eye injuries. Many of these lessons were learned in World War II and because of excellent teaching by our predecessors were well applied in Korea. Other mistakes obvious in the last war were repeated in Korea. These were notably the lack of an adequate field chest for the ophthalmologist and the total absence of any protective device to prevent eye injuries. It was well established in Korea that ophthalmologists can and should be assigned to forward installations to render treatment to eye casualties as soon as possible. Rapid evacuation especially by helicopter and airplane has been a major advance in the conservation of vision.

It was also well established in the last war that the timeworn priorities of war surgery—the saving of life and limb—were superseded by a more realistic approach—the saving of life, *vision*, and limb. A few of you may argue that it is better to die than to be blinded, but I am sure none will disagree that it is better to lose a limb than one's eyesight. If the same trauma which causes a minor injury elsewhere to the body involves the eye, a serious handicap results. It incapacitates a soldier in battle and may necessitate evacuation to the Zone of Interior. A survey of eye wounds in Korea by The Surgeon General's Office in 1951 revealed that 81 percent required evacuation to the United States. The majority (some 85 percent) of those injured in other areas of the body were returned to duty. When one hears the figures of about 5 percent of all *battle* casualties involving the eyes, and 10 percent or more, of *noncombat* injuries, it does not sound

*Presented 23 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

high. Most of these result in some compensation, however, and many millions of dollars are being paid now to those who received ocular wounds in Korea.

I shall not elaborate further upon the importance of an eye injury, especially in combat. Most of you have had first-hand experience with that. At this point, however, I am sure many of you have the question on your minds, "Just what *should* the general surgeon or medical officer do when he is faced with an eye casualty?" In a talk which I presented several years ago before a national society, I concluded with the statement that "the Army ophthalmologist will gain much experience as a result of the Korean conflict, fully realizing, however, that wars do not teach us what to do, but rather what not to do." I am sure that this statement holds true for *every* medical officer.

The Committee on Trauma of the American College of Surgeons has recently published *its* policies regarding the treatment of acute injuries of the eye. It feels that the early care of ocular injuries by nonophthalmic personnel should be limited to absolutely essential first aid, and thereafter, to refraining from doing harm. The most trivial eye wound may result in total loss of vision, and therefore, they state that every injury of the eye is potentially serious. The Army has long recognized this and labels a high priority for evacuation of eye casualties. The eye damage must be carefully assessed, as improper examination may result in the total expulsion of the ocular contents through a small and perhaps unrecognized wound. The operation of enucleation is never an emergency procedure, and it should be reserved for the ophthalmologist. It is the most *final* of all eye operations just as the amputation is for wounds of the extremities. The only criticism a general surgeon can receive in treating wounds of the eyes is in doing *too much*—never, too little.

Major Edwards has mentioned the fact that most eye wounds are accompanied by other injuries. It is the surgeon's responsibility not to overlook serious damage to the eyes by directing exclusive attention to other major wounds. The primary operation upon an eye is usually the definitive one and the surgeon seldom has a second chance. This responsibility should therefore be placed upon the eye surgeon who is charged with definitive care. The complete examination which is necessary before surgery demands specialized equipment; this equipment and the small delicate instruments which are required for ocular surgery are not usually available to the general surgeon.

After examining the patient's eyes the medical officer *should make careful notes* of his findings. These will be of great value later to the ophthalmologist. The patient should then be evacuated as soon

as possible, preferably in a smooth-riding helicopter rather than an ambulance, as a litter patient with both eyes bandaged. The bandages are worthless and may be harmful unless they are firmly and tightly applied to prevent any winking or motion of the eyelids. It is well to sedate the patient to allay the fear and apprehension which usually follows covering both eyes. Opiates may be used unless, of course, they are contraindicated in the presence of a head wound.

The next consideration in the emergency care of the eye casualty is the prevention of infection. *Minor trauma* does not demand as vigorous measures as more serious injury. Overtreatment should be avoided and the indiscriminate use of antibiotics is to be condemned. There are many antiseptics and chemotherapeutic agents available for use as local bacteriostatic agents for minor trauma. Zephiran, furacin, metaphen, merthiolate and propionic acid may be employed. Boric acid, argyrol, silver nitrate, zinc sulfate and yellow oxide of mercury are *not* recommended as dependable in prophylaxis. Chemotherapeutic agents such as the sulfonamides are well applied following minor trauma. Antibiotics are unnecessary, and indeed much harm may result from their indiscriminate use ranging from local allergy to general sensitivity, and the development of bacterial resistance and cross-resistance, or superinfections.

In *major extra-ocular trauma*—which to me should include corneal abrasion in addition to severe lacerations of the lids, conjunctiva and adnexa—every effort is demanded to prevent infection. Antibiotics are usually preferred and they may be employed locally and systemically. Penicillin should not be used locally as allergy is frequent and there are more organisms resistant to penicillin than to any other antibiotic. As you know, this is variously estimated as 30 to 48 percent for Staphylococci, and Streptococci may also be resistant. All antibiotics penetrate the intact cornea poorly except for chloromycetin. Sodium sulfacetimide pentrates better than other sulfonamides. They all penetrate the abraded cornea well. The action of ointment is more prolonged than that of solutions; however, this vehicle is contraindicated in a perforating wound of the eyeball. Many authors recommend the local use of antibiotics (or combinations) which are unlikely to enjoy widespread systemic use because of their toxicity, such as bacitracin, neomycin and polymyxin. We prefer the combination of terramycin and polymyxin which offers powerful antibacterial action against gram-positive and gram-negative organisms including *Pseudomonas aeruginosa*. This bacillus, the pyocyaneus, was common in Korea and is much feared by the oculist. It causes a fulminating infection which may result in total loss of the eye in a matter of hours.

In *severe ocular trauma* which involves penetration or perforation

of the eyeball, drastic attempts must be made at once to prevent infection. Once an intra-ocular infection occurs, the prognosis is very poor and the eye is usually lost. Local antibiotic prophylaxis must be supplemented by oral or parenteral therapy. I mentioned that procaine penicillin combined with streptomycin, intramuscularly, is an effective prophylaxis in trauma to the eyelids and adnexa. It penetrates the eyeball poorly, however, and is not recommended for the prevention of intra-ocular infection following a perforating wound to the globe. As you know, the absorption of intramuscularly administered antibiotics is retarded and erratic in shock. This combination did not produce a satisfactory concentration in wounded tissues in Korea. Later in the war change was made to aqueous penicillin G, administered intravenously at the battalion aid station level, as soon after wounding as possible, in doses of 500,000 to 1,000,000 units every 8 to 12 hours depending upon the severity and multiplicity of injuries. Streptomycin 0.5 gram is given at the same time. This is excellent prophylactic therapy for a penetrating ocular wound.

In brief, after examining an injured eye, if the wound is external, a local sulfonamide should be applied and this may be supplemented by intramuscular penicillin. If the wound perforates the eyeball, a local antibiotic in solution form (not ointment) should be supplemented by massive doses of aqueous penicillin G with streptomycin intravenously. As most eye casualties also suffer from other injuries, this latter therapy will usually have already been administered.

Major Edwards has also recommended that the ophthalmologist be supplied with better instruments for diagnosis and treatment. Figures 1 and 2 show the small eye field chests which were available in World Wars I and II. They were totally inadequate and were the cause of much criticism by civilian ophthalmologists in the Army during the last war. In Korea there was *no* field chest available and the ophthalmologist had to use what he could obtain through normal supply channels. Many of them supplied their own instruments. I have been told that stones from the beaches have been used as orbital implants following enucleations in some instances because of the lack of proper plastic implants. The Ocular Research Unit here at Walter Reed gave a high priority to the development of a modern eye field chest during the Korean conflict. This chest (fig. 3) was given a field trial for a time during the last year of the war, and it is presently in the process of standardization. It contains all of the equipment, in miniature form, which is available in any well organized eye section. Much research was required to develop many of these items, which include a miniature slit lamp, a small hand electromagnet, a lightweight folding perimeter and fine eye-cutting instruments with changeable blades.

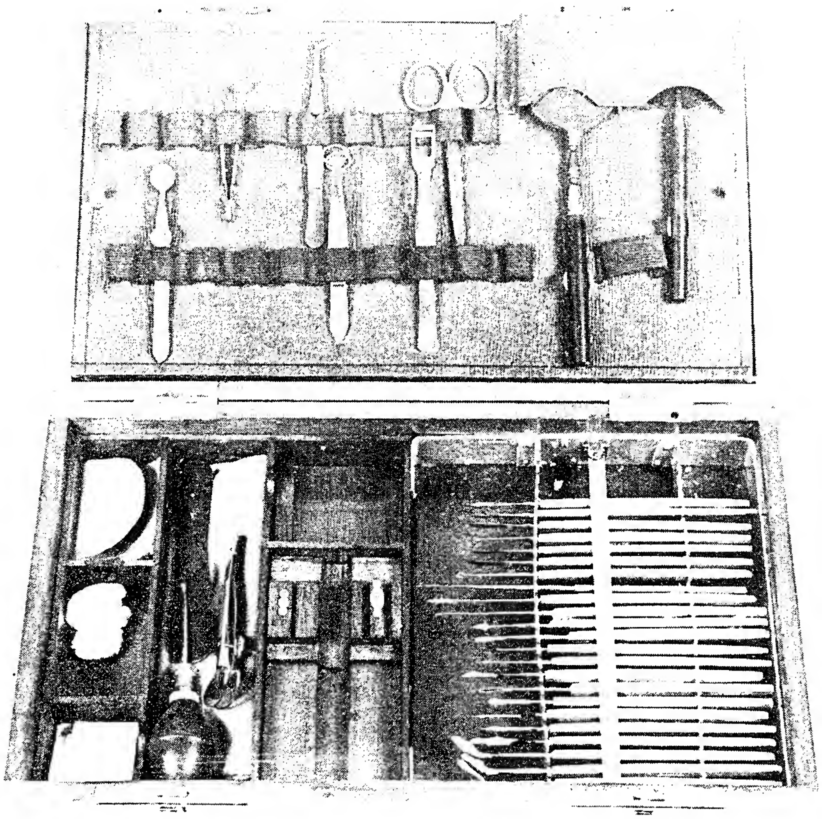

FIGURE 1. World War I eye field chest.

There is also a modern set of implants to be used for enucleations, and a miniature refracting unit.

Major Edwards has also recommended the use of protective glasses to prevent eye wounds resulting from small particles. We have also been concerned with this serious problem. The Ocular Research Unit held numerous meetings attended by national experts in industrial ophthalmology; Army, Navy and Air Force specialists; and foreign scientists; in an attempt to recommend the proper protective device. The Surgeon General transmitted these findings to the Quartermaster Corps 6 months before the truce, over 1½ years ago, recommending the trial of certain types of commercial industrial protective eyeglasses in Korea. To date we have not received any progress reports despite numerous inquiries.

I shall not have time today to discuss the ocular conditions of repatriated American prisoners of war from Korea. Of the 148 released in Little Switch, 40, or *27 percent*, suffered eye disabilities. In Operation Big Switch, 3,596 were released, with 93, or 2.6 percent, eye casualties. About 15 of these have been discharged as totally blind from ocular disease secondary to avitaminosis and malnutrition.

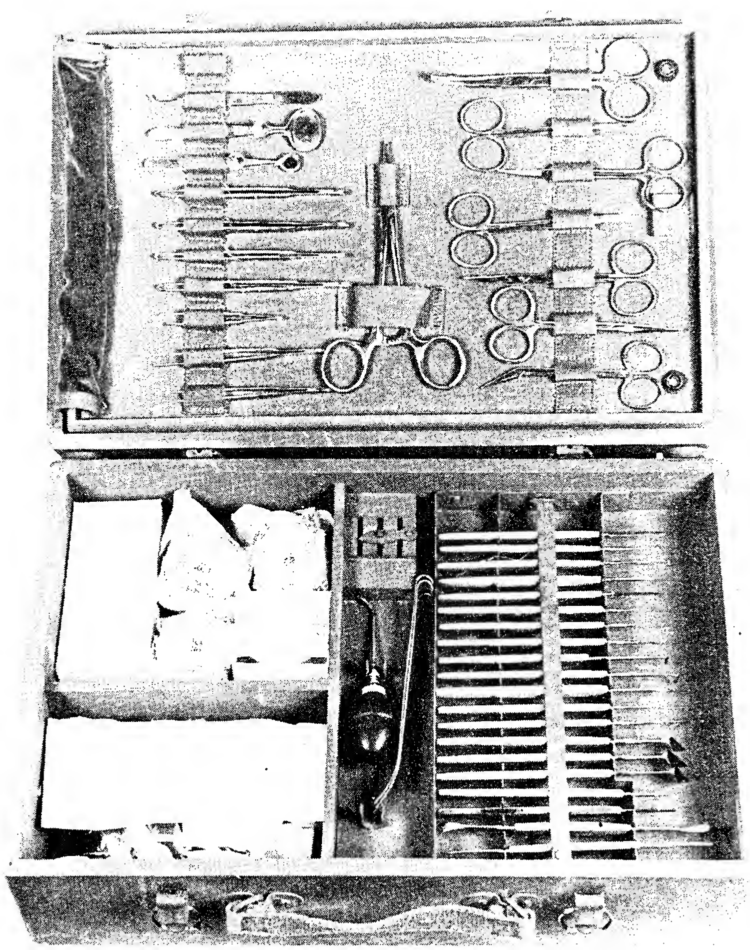

FIGURE 2. World War II eye field chest.

In conclusion, I should like to thank Major Edwards for his fine presentation and for the privilege of allowing me to discuss it. Great credit is due the young ophthalmologists who performed so well in Korea and kept the loss of eyes at a minimum figure.

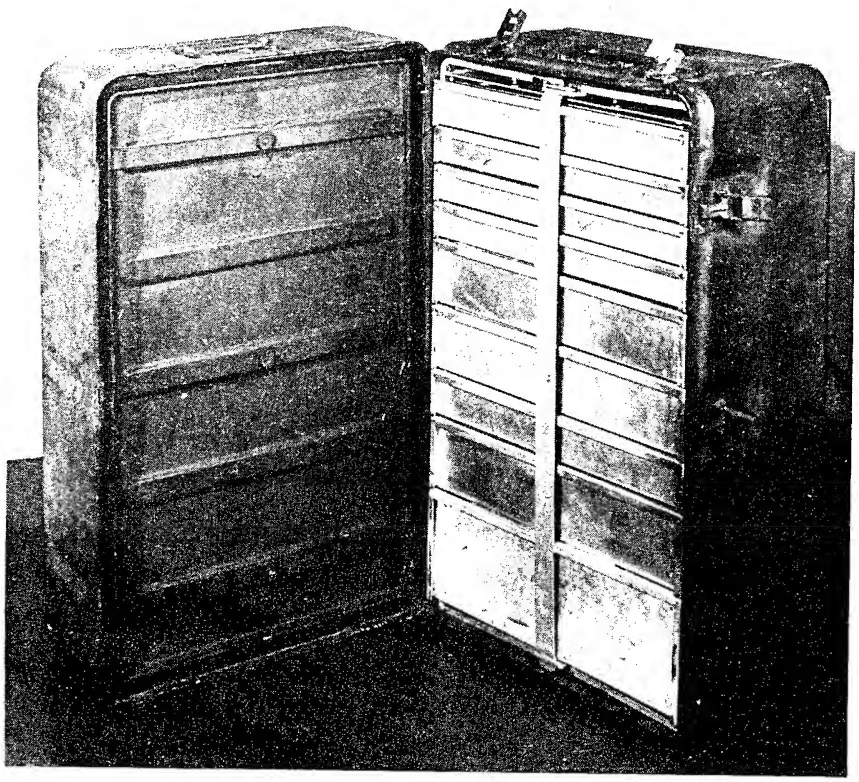

FIGURE 3. New eye field chest.

FRIDAY AFTERNOON SESSION

23 April 1954

MODERATOR

COLONEL BERNARD N. SODERBERG, MC

PLASTIC SURGERY REPAIRS IN KOREAN CASUALTIES*

Colonel Bernard N. Soderberg, MC

In this presentation we wish to discuss definitive management of regional traumatic defects in Korean casualties. Patients arriving from zones of conflict have shown improved wound care. The early wound healing has resulted from judicious use of the free skin graft. In most cases, this has seemed to preserve much extremity tissue. In the head and neck region, preservation of soft tissue parts, coupled with early architectural fixation, has allowed the salvaging of many features. The rapid wound healing has presented these patients to the reconstructive program at an early date, and has reduced the number of definitive plastic operations.

In general, reconstructive surgery has not been begun until scar tissue has become soft and mobile and all peripheral tissues have returned to normal. Each surgical step has been devised to add improvement to that obtained by the previous operation. Ordinarily areas of motion have been treated first. Surgery of the nose, eyelids, oral orifice and neck has been necessary to improve the airway, protect the eyeglobe from exposure and trauma, to remove the feeding problem, and to prevent neck contractures that fix jaw positions, exposing the oral area. Repairs of extremity parts have dealt first with the flexor and circumferential lesions.

The Free Skin Graft

The free skin graft has been frequently used for definitive repairs. As a type of transplant, it can be had in variable thicknesses, up to and including all the corium. The requirements of the recipient site determine the degree of thinness or thickness of the skin graft. Thin grafts are indicated to obtain early wound healing. The thicker graft is more valuable for definitive repairs. In general, the requirements of the recipient site determine the thinness or thickness of the skin graft. Each thickness of graft has individual characteristics. The thinner the graft is cut, the more apt it is to take. Thin grafts con-

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tract with passage of time to a greater degree than do thick grafts. Protective coverage to the part is proportionately decreased with the thinness of the graft.

For definitive procedures, the choice free graft is one that is cut approximately three-fourths the skin thickness. At this cutting level, sufficient skin elements are left in the donor area to permit spontaneous healing in 12 days. Epithelization is accomplished by the process of dedifferentiation from deep glands or hair follicles. The three-quarter-thickness skin graft can be made to take perfectly only in clean surgical fields. In the past, plastic surgeons have chosen the full-thickness graft for definitive plastic surgery because it offered the maximum coverage qualities to the recipient site, contracted the least during the postoperative course, and usually offered a better color match than the thinner graft. A drawback, however, was the fact that the donor site, if the graft was large, had to be skin grafted from elsewhere to get closure. The three-quarter skin graft, however, has now proven definitely equal to the full-thickness cut in regard to fundamental characteristics. It offers an additional factor, that if cut by machine and properly applied, it will take 100 percent. A full-thickness graft is always cut by scalpel and carries an overall percentage loss in take up to 20 percent.

Recipient sites for free skin grafts in addition to blood supply also have individual characteristics which influence serviceability of transplant. The stability of architecture influences graft contracture. Thin grafts of nonresilient backgrounds contract little, while those on soft mobile structures contract the most. Examples would be the forehead in the former, and the neck in the latter. When drawing up in the graft site occurs, further grafting has to be done to release the contracture. This process continues until surface replacement equals surface loss in volume, area, and character.

A practical point is noted in the attempt to overcorrect a region in anticipation of subsequent contraction. Skin grafts will take, if fundamental surgical principles are not violated. There must be proper and complete apposition of the graft to the part. Immobilization must be present for 14 days. Grafted clean wounds do not usually require a dressing under 8 days. Where the skin is over a granulating area, the first dressing change is done on the fourth postoperative day. Continuous wet dressings are used in this latter situation. Fibrous attachment of a skin graft is not complete until the fourteenth postoperative day. Up until that time, it may be slipped on its site and lost.

Before the skin graft is applied, the recipient area is completely freed of fibrosis, and hemostasis is accomplished. Infection must be

absent. In the granulating wound, on the other hand, the recipient situation by specific preoperative care is made relatively free from bacteria. Granulating sites ready for grafting are cherry red in color. They are nonedematous and there is no peripheral cellulitis. The thinnest type of graft is to be used in this situation.

The free skin graft must cover a denuded area having a good blood supply in order to survive. The recipient site, therefore, is a determinant in the choice of soft tissue coverage. The pedicle flap, in contrast, relies upon its own blood supply through its pedicle. Obviously then the use of the free graft would be for coverage upon fresh, clean denuded areas possessing a healthy, vascular supply, and the flap would be best to cover recipient sites possessing poor blood supply. The free skin grafts as a type of transplant can be had in variable thicknesses.

Several ways of handling the granulating surface prior to graft have been followed; each has its own merit. It is felt that, where it is feasible, avulsion of all granulations just before application of skin graft is the preferable method. Where the granulating area is on an extremity, a tourniquet can be applied above the lesion; this method is quite satisfactory. With the use of antibiotics, a somewhat thicker type of graft can be made to take. Results may be such that no subsequent definitive skin graft will be necessary. This then would eliminate much hospital time and subsequent operative procedures for patients. However, in general, it may be stated that for early healing of wounds, the thinner graft is used.

The homografting procedure, combined with the autograft, offers a method of application. For example, in one case 7 donors supplied 14 segments of skin measuring approximately 4 by 8 inches each. These pieces were united to form a large blanket. Four segments of the patient's own skin were applied to the buttocks area and the blanket added to cover the remaining granulating area. The whole application procedure lasted less than an hour.

Unusual accidents from trauma occur now and then. These may present problems in surface coverage application. One patient, a motorcycle casualty, sustained the avulsion of the entire leg, genital organs and one-half of the bony pelvis. As an emergency procedure, the full-thickness skin and subcutaneous tissue was removed from the avulsed extremity and used as an immediate coverage. It is obvious that such an addition, without a tube to supply blood, would die. However, it served as a lifesaving procedure and remained in place until sufficient granulations formed. Débridement was accomplished in stages. The completed area with preoperative cleansing presented a recipient site adequate to receive a free skin graft. The

closure resulted in a relatively firm diaphragm. This is in contrast to a recent similar case in which the patient was treated by using a first stage repair, a free skin graft with adherent subcutaneous tissue. The graft take was successful, but to date the diaphragm so formed is thin and fluctuant, indicating the possibility that for final repair, a pedicle flap will have to be substituted.

Occasionally long one-piece grafts can be used effectively. This is especially noted in hands and arms. One method that we use employs the replacement of the dermatome drum without graft severence. The continued cutting then gives a double drum length of skin. The method of re-splitting skin grafts, described by Zintel, Marcus, White, and Dupertuis, doubles the donor material available and may eliminate the necessity of homografting in some situations.

In the early treatment of large open wounds with granulating surfaces, the avulsed wounds may be healed by coverage with a free skin graft. Subsequently, this entire segment may be excised, the adjacent skin undermined and advanced to produce a single line closure. This type of repair procedure is especially desirable when the soft tissue covers mobile parts.

In the definitive or late stage, surface repairs are frequently indicated. The residual scar contracture is excised and the denuded area covered with a three-quarter-thickness dematome cut graft. Vaseline gauze is applied directly over the attached gauze, followed by a superimposed moistened cotton layer cut to pattern shape. These two layers are firmly approximated to the recipient site stent fashion, using gauze fluffs. The peripherally placed long sutures fix the modeled pack in place, pulling the recipient site and graft together as an immobile unit.

Reference is made at this time to procedures of plastic surgery in children for comparisons of related cases. In children, the institution of free grafts follows the growth curve. Ordinarily it is best to wait as long as possible for complete scar softening before definitive repairs, but one should always act before serious contractures occur. In one infant with a severe burn scar contracture involving the axilla, arm, forearm and hand, the first operation eliminated all contractures by excising limiting cicatrix and supplying normal coverage. The free grafts used were obtained from the abdomen. In such cases peripheral long sutures tie over gauze packs in the axillary space. This eliminates the old method of circular bandages alone for fixation and their concomitant circulatory hazards.

In hands, free graft coverage is always best. This type of skin might not be indicated when intrinsic repairs are necessary. In this situation, a pedicle flap would be required.

FRIDAY AFTERNOON SESSION

The Tube Pedicle

Skin tube pedicles as separate units have been frequently employed when coverage by open flap could not be conveniently designed. The skin tube offers a clean, healed, soft tissue transplant having migratory features not otherwise attainable.

The initial construction of the tube pedicle on the abdomen begins by parallel incisions through the skin and subcutaneous tissue to the fascia. This flap of tissue is undermined completely, using care not to buttonhole the fascia. Complete control of blood vessels, not only from the fascial area, but also flap adipose base, is imperative. Hemostasis, if neglected or masked by novacain adrenalin anesthesia, may subsequently spell disaster.

The tissue flap properly prepared has its cut edges united forming the skin tube. Closure of the subjacent denuded area can be brought about by a variety of methods depending on the location, size of the tube formed, personal experience and training of the surgeon. When tubes are small, adjacent undermining of soft tissue mobilizes it for closure. This, if done, should always be accomplished without tension. If the latter is present, healing usually occurs with scar formation. The width of scar is directly proportional to the degree of tension. If the tube is to be large, closure is best by added free graft. The periphery of this graft is mattressed to the skin and subcutaneous tissue of the recipient border. The free graft is approximated and fixed by a form-fitting stent-type dressing. These tubes, if large, must be prepared before transfer by band constriction or delay procedure at the end to be moved prior to transfer to recipient site.

Another method is to use the intermediate carrier but eliminate some of the stage procedures. For example, the arm may be used and the flap applied as a forehead soft tissue reconstruction. In this case a bone graft to complete skull continuity may be needed also. In some situations showing forehead defects, residual soft tissue is adequate so that only bone is necessary to complete the reconstruction. Grafts are usually taken from the ilium.

Intermediate carrier transfers occasionally may be needed in jaw reconstruction, where massive bone grafts are necessary to rebuild the mandible. The abdomen may be preferable as a soft tissue substitute for it is the thickest material at hand. This soft tissue skin surface of the transplant rarely matches the adjacent facial skin. To improve the facial appearance after architectural repair is complete, the surface pedicle skin can be excised and the adjacent facial skin mobilized over the summit of the added subcutaneous tissue.

The Open Flap

The open flap differs from the tube in that the flaps are left open in continuity. These flaps are placed directly on the recipient site. The raw areas, both donor and free flap base, are free grafted in order to present a completely healed postoperative lesion. In cases where all denuded areas are "skin dressed," the pedicle can be immediately imbedded. The second operation then completes the procedure.

The abdomen is the common site for open flaps. The free skin grafts may produce early healing, eliminating the fibrotic phase. It may be necessary to substitute a flap in order to have soft tissue coverage that would insure an adequate soft tissue bed for intrinsic repair.

Flaps in general are constructed so that they completely cover the defect. They are attached without tension and in a manner so that the free area of the flap, joining the body completing the vascular continuity, does not bend or kink. If this allowance is not observed, nutritional supply is jeopardized. Small sharp bends may, if subjected to subsequent edema, be converted into pressure kinks which will destroy the vascular supply to the transplant. The periphery of the flap should be carefully approximated to the wound circumference.

The anterior chest offers a flap of thinner character than the abdomen and may be the choice for certain defects of the hand. Complete avulsion of the integument and tendon fascia in many places involving the index and long fingers of the hand was treated by immediate insertion of the digits into a skin pocket. The definitive procedure consisted of removing enough attached thoracic skin and subcutaneous tissue to completely wrap around the fingers. In one case, three delay procedures were felt necessary before complete detachment.

The open jump flap popularized in World War II has been used frequently and seems to be a somewhat faster procedure for the transportation of large tissue masses than in certain combined flap types. This, however, is a variable thing for much depends on the individual operator.

Good results have been obtained by resurfacing both legs in preparation for bilateral bone grafts to the tibia. In one case of this type, one extremity had a rather large defect and required a transference of soft tissues that would cover approximately two-thirds of the lower leg. The open jump technic was employed with the arm as intermediate carrier. The left leg, having a smaller defect, but requiring good coverage, was repaired by tube pedicle transplant from the abdomen.

In lower extremity resurfacing for deep surface defects, several methods have been found satisfactory. The immediately rotated flap has been useful with a skin graft covering the denuded site. This type

of tissue transfer, properly done, carries added circulation to the recipient area. Parallel double pedicle shifts can sometimes be used where lesions are susceptible to these reparative procedures. Rapid repair, shortened convalescence and facilitated postoperative care are the benefits of both these methods. The recipient site determines the technic of soft tissue transfer.

The cross-leg open flap has been utilized and can be a one-stage affair, depending upon its location. In general, for lesions on the lateral leg or foot, cross-leg pedicles will have to be located in situations which, because of blood supply, necessitate a delay procedure to augment vascularity. Meticulous surgical care is paramount. An improperly or inadequately delayed flap will subsequently show marginal or continuity losses. Flap destructions due to improper design or surgical technic are dreadful things and greatly multiply hospital time.

By and large, lower leg flaps are easier and more certain to be successful than thigh transplants. Thigh flaps are indicated, however, where a larger amount of subcutaneous tissue is required. They may also be indicated where a cross-leg flap has been previously lost, or there are amputation prohibitions. Inner thigh tubes and reverse suprapatellar flaps in general are successful.

When the open calf flap is used, the split distal end allows the transplant to cover a bilateral defect of the ankle. Tube pedicle defects of the sole of the foot are infrequently used as transplants and are much more time consuming in comparison to the open flap cross-leg technic.

Face and Jaw Repairs

For face and jaw wounds, the basic procedure plan has been outlined previously. This worked successfully in World War II. It is thought of as a basis that may be modified according to terrain and hospital facilities available. The following plan for early care is outlined:

As soon as an individual sustains a facial wound, three things in his care must be of immediate concern: the cessation of hemorrhage, the establishment of a free airway and the stabilization of the parts. One may attempt to stop bleeding, first, by applying digital pressure on known parts. This pressure, when applied, should be properly located over a feeder blood vessel and in such a way that the blood vessel will be compressed against some hard structure. Control of hemorrhage may be accomplished by the application of pressure through a gauze pack. This gauze pack is helpful for inaccessible bleeders. If hemostats are at hand, the lacerated vessel can be clamped and tied. It is important to bear in mind that tissue should not be manipulated more than necessary, for it is possible to advance infec-

tion into deeper recesses. If the gauze pack is employed to stop bleeding, its pressure must be maintained continuously for a period of time. It is not necessary to put great pressure through a gauze pack. Such pressure, improperly applied, may strangulate structures. A small amount of pressure, properly placed, will collapse the vessel. The gauze pack should be held with moderate pressure.

To insure an airway, an immediate attempt may be made to remove blood clots and foreign material from both the mouth and the nose. A rubber tube slipped through the nose or over the dorsum of the tongue may be helpful. When the tongue drops back in the throat as during an unconscious state, or from lack of support because of fracture of the mandible, the attendant may lift up on the tip of the chin and pull out the tongue. The applied method is similar to that which is used occasionally while giving an anesthetic for a surgical operation.

The preliminary stabilization of bones and soft tissue is the third goal. The movement of injured parts jostling around may cause the recurrence of hemorrhage or occlude the recently established airway. This movement is painful as well, and therefore may be considered a shock factor. Stabilization at this stage may be accomplished by some simple means; the Barton bandage has been the most helpful method for temporary control. Members of the Medical Department in combat zones ordinarily are supplied with first aid packets. These sometimes are admirably adapted for the treatment of facial wounds. The compress with its lateral tail can be used as a sling to hold and support torn and loose tissues. If gauze packs are not available, the compress itself can be separated from the bandage part and used as a pack or dressing.

In combat zone care, tracheotomy should be considered as a last resort, for at this stage, actually little more can be accomplished than the application of the compress and the four-tailed bandage. Where intrinsic fractures of the bony architecture are present and a dental surgeon is available, some temporary splinting of the teeth by application of wires may be feasible. Intermaxillary rubber band fixation would be the only consideration, and even this would not be applied if transportation or evacuation is to be accomplished unattended by Medical Department members. The object in preliminary treatment will be to prepare the patient rapidly and adequately so that he may be transported to a station back of the combat zone where he may receive more specialized treatment.

Proper positioning of the patient for transportation may reduce the mortality rate in the maxillofacially wounded individual. If he is ambulant or semiambulant, it would be well for him to be transported

sitting up. If he is a litter case, position would be face down, if there would be any danger of obstruction of the air passages.

Where time is favorable and the setting proper, one may attempt some early care. If this is possible, the surgeon will attempt to save all the bone and soft tissue possible, remembering always that it is better to leave tissue that may die than to cut away some that may live. A few treatment cautions would be: Do not remove fragments of bone that are attached to periosteum or muscle; do not probe around for foreign bodies; débridement is not indicated as part of first aid treatment; parts must not be manipulated any more than is absolutely necessary for the purpose of stopping bleeding, establishing the airway, or stabilizing the parts.

At the first hospitalization, if conditions are appropriate, the routine would be, first, to check for breathing and free airway, second, to consider the patient as a neurological problem, and third, to examine the wound. In this latter care, one looks for fractures of the bony architecture, checks for lacerations or tears into the mouth, into the nose and conjunctiva, examines the eyeball, checks the function of the seventh nerve, examines for bony and soft tissue obstructions of the nasal airway and damage to the parotid duct. X-rays will help reveal the presence of fractures and also nasal sinus involvement. It is important to check the condyles of the mandible, to palpate the orbital border, the frontal bones and the whole zygomatic area.

Primary repair is best achieved before swelling and infection occur. It is preferable to carry out the surgical procedure in the first 12 to 20 hours. Time lapse between accident and wound closure depends upon the kind and type of wound present and surgical judgment. For example, it is well known that infection sets in early in contused and crushed tissues. A clean-cut laceration can be united as long as 24 hours after injury with good results. We would delay primary repair in the presence of neurological damage. Jaws would not be fixed until the patient was free from vomiting. The anesthesia preferred would be local, infiltration and nerve block, bearing in mind that the wound edges are sometimes insensitive. General anesthesia is avoided if possible. Débridement is carried out on the wound if it is indicated. This begins with cleansing by using saline solution, soap and water, with ether as a solvent. Foreign bodies are removed. Surgical excisions are limited. Only obviously dead tissues are excised. Radical surgery sometimes destroys what later might be salvaged as a feature. Attempt is made to conserve bone fragments. Any portion of bone that is attached will be left in place. Those exposed will have the areas covered by suture of adjacent soft tissue, if possible. Occasionally soft tissues are disrupted and torn away with much bone

exposure. Direct fixation is sometimes considered; when this is accomplished, drains are left in place.

Types of fractures of the maxillae are many and varied. Sometimes they may occur singularly or in combination. Recent fractures of the mandible, which show no bony loss and are associated with no fractures of the superior maxilla, are generally treated best by the simple method of intermaxillary rubber band fixation. The upper jaw is used as a splint. The displaced fragments are reduced by the utilization of the rubber band traction. The multiple loop intermaxillary wiring with intermaxillary rubber band fixation has been shown by Stout to be the one most applicable for the early care of the war wounded. It carries the least danger in fracture reduction, and in many cases gives the best results. Splinting of the jaw for bony fractures is instituted as soon as the patient's general physical condition has become stabilized.

Through-and-through bone wiring for fragment control ordinarily is contraindicated. The dangers are: rotation distortion, necrosis around the wires and unnecessary compounding of bone. External pin fixation is contraindicated, except when attempted by experts, then only when insufficient teeth are present. External pins do not always hold securely and cannot be considered practical as front line procedure. They tend to loosen in the bone, permitting undue fragment mobility, and unless aseptically inserted, cause scar dimpling of the face, which sometimes results in permanent scar tissue deformity.

In the case of the edentulous mandible with fracture, circumferential wiring about a superimposed form-fitting splint is the most satisfactory method for general use. The early care of the fractured mandible showing bone loss near the angle of the mandible needs no special treatment. Simple splinting of jaw to jaw is sufficient. When lateral losses necessitating bone graft are present, no attempt is made to control the posterior edentulous fragment, unless a transplant is anticipated within the succeeding 3 months. The anterior superior displacement of the ramus fragment does not interfere with the mechanics of occlusion during the preliminary period, and it can be more advantageously cared for later. Where the fracture line in the inferior maxilla lies posterior to the last occluding molar, some difficulty may be incurred from the action of the elevator muscle. If healing is permitted with the resultant displacement, the patient may eventually be unable to open his mouth normally.

Occasionally a second or third molar is present and situated in such a way that its position in the fracture line maintains the posterior fragment in the proper place. In such an instance, the tooth would be allowed to remain in the fracture line for it would act as a wedge splint holding the posterior fragment in place. After about 3 weeks

the surrounding soft tissue would be sufficiently firm to hold the fragment in proper alignment. At that time the tooth could be removed; if allowed to remain, it might continue to act as a foreign body, inhibiting proper healing. If no tooth is present to hold the ramus downward and backward, special intra-oral splints may be made to hold the fragment in position. An alternative method would be transosseous wiring or the modified tantalum plate. Posterior traction by means of silver wire passed through the bone is now only occasionally employed.

In the case of the partially edentulous jaw, where it is necessary to do intermaxillary fixation, the use of the half-round arch bar is satisfactory. Cross-wires are passed over the arch bar to obtain proper fixation. The sectional splint introduced by Stout is valuable as well. Ordinarily little or no displacement is seen in fractures of the ramus of the mandible. This is largely due to the muscle protection given by the pterygoid and masseter. Simple fixtation of the lower to the upper teeth suffices. This is also the usual treatment in fractures of the neck of the condyle. Infrequently the occasion is such that open reduction is indicated.

Fractures of the superior maxilla are seen in all degrees, from the separation of small areas of the alveolar ridge to the complete separation of all the upper facial bones from their attachment to the cranial base. Associated complications vary from simple ecchymosis and swelling of the soft tissue up to large lacerated wounds with associated fractures into the nasal fossa and sinuses. Every attempt should be made to replace the bone fragments in their proper anatomical position as soon as possible for bony union takes place quite rapidly in this area. Accuracy here is quite important because slight variations from normal make noticeable variations in contour as well as influencing proper aeration and sinus drainage. Replacement is obtained by mobilization and constant pressure exerted in an upward direction.

The reconstruction of occlusion and maintenance of position can be brought about in several different ways. A heavy arch bar may be secured to the teeth with wire ligatures. This in turn may be attached to a plaster head cast by metal side arms. This method permits mobility of the lower jaw. If there is some doubt about obtaining proper occlusion, one may do intermaxillary wiring, securing the mandible in addition by an arm bar to the plaster head cast. In some cases, all that may be needed would be a felt cap chin appliance associated with intermaxillary fixation.

In any injury of the upper facial bones, one should look for possible involvement of the zygomatic arch and malar bone. The side supports of the latter are usual sites of fracture. It is not uncommon,

however, to see the malar bone driven backward and downward and impacted in this position. These depressed defects sometimes cause fearful deformities; care must be instituted within the first 10 to 15 days, as replacement can be impossible after 2 weeks. The depressed malar may sometimes inpinge upon the coronoid process of the mandible, mechanically interfering with jaw movements.

Fractures of the orbital rims and floors also may be associated with displacements of the malar zygomatic compound. Fracture displacement of the orbital floor and lateral orbital rim is associated with downward and backward displacement of the eye globe. Upon clinical examination where this has occurred, there is a resulting one-sided flatness of the face. There is a definite pupillary descent as measured against the unaffected side, and the skin fold in the upper lid appears deeper than usual. The patient may complain of diplopia; this may be transitory or permanent. The lateral canthus of the eye may also be displaced. By palpation, one may notice a steplike notched defect of the lower orbital rim.

When the malar bone is impacted into the antrum crushing through the anterior wall, splinters and spicules may be present in the antrum as foreign bodies associated with hematoma. Several surgical technics have been employed to replace these structures. Extra-oral approach has been valuable in some cases. It has seemed that the intra-oral approach has been found to be the most satisfactory in the majority of situations. In the former, the approach is through the temporal region. An elevator is passed between the muscle fibers and the temporal fascia, forward and downward, to the medial surface of the bone. The depressed fragment then is elevated into place by leverage, aided by the insertion of a gauze roll beneath the elevator as a fulcrum. This method is indicated for depressed fractures of the zygomatic arch.

Interference caused by the masseter muscle sometimes contraindicates the intra-oral approach for this defect. Intra-oral approach to the antrum through the canine fossa allows the surgeon access to the depressed orbital floor plate. After the anterior wall of the sinus and malar has been elevated out of the way and loose spicules of bone and hematoma removed, one may replace the orbital floor. The gauze pack is left in place to maintain position. This should not be packed too tightly. It can be removed after a few days through the canine opening or through the newly formed naso-antral window. When it is difficult to maintain the reduced position, interosseous wiring of the frontal process of the zygoma to the lateral orbital rim may be necessary. A small external incision in the involved area suffices for approach. Stainless steel wires are satisfactory. These are passed

through drill holes in both segments, reestablishing the continuity of the frontal zygomatic bones.

Bony fractures are sometimes associated with soft tissue defects. In attempting this type of repair, it is well to have a basic plan in mind. The assemblage should begin from some known point. This might be the vermilion border of the lip or nostril border or eyelid margin. If it is impossible to find a key point to start the soft tissue repair, one attempts closure by placing the first suture in the center of the wound and bisecting the remaining segments. These methods are helpful also in replacing loose flaps. One attempts to unite the parts with normal appearance as the goal, but there is never any attempt made to improve the patient's natural appearance. The sutures when placed may be deep, but never wide. In some situations, stay sutures can be introduced from the inside. If they must be placed outside, they are left long and tied up over the broad gauze pack. Such sutures should be removed in 3 to 4 days.

We would like to say in closing that the quality of results in Korean casualties has depended not only upon the definitive procedures, but in a large part upon the superior care given these patients in the early treatment performed in other theaters. Methods of early care have recently been studied by Colonel Chipps, who has shown procedure modifications that were successfully established in the Far Eastern Theater. The recent studies of over 1,000 cases by Chipps, his personal work, have been helpful in showing the attainment of better results in all definitive centers.

It is with great pleasure that I say we have Colonel Chipps with us today to tell of his experiences in the early care of facial casualties, which have played so great a part in the superior results that have come out of facial wound care in Korean casualties.

MAXILLOFACIAL INJURIES*

A Supplement to the Discussion of Specific Primary Considerations in Plastic Surgery, presented by Colonel Bernard N. Soderberg

LIEUTENANT COLONEL JAMES E. CHIPPS, DC

This is a supplement to Colonel Soderberg's discussion to further emphasize the importance of early treatment of maxillofacial wounds. In the allotted time, only two points will be considered. First, the reduction of bone fractures and closure of soft tissue injuries as much as possible at the primary stage is of such benefit in the restoration of function and curtailment of later major reconstructive procedures that it is essential to proper maxillofacial surgery that such treatment be rendered. Second, too few patients have received this beneficial primary treatment in the past and the percentage can be improved upon in a future emergency.

Since Colonel Soderberg has adequately discussed the methods of primary treatment, only the results in a few cases need be shown in making the first point. Some of these wounds were treated in the first few hours in Korea before marked inflammatory reactions had occurred. Others were first treated in Japan after a necessary short delay for preparation of the infected wounds but before the response to injury had progressed to fibrosis.

Figure 1 illustrates a patient 14 days after sustaining severe stellate wounds of the right and left sides of the face with primary avulsion of the entire body of the mandible, the entire tongue, most of the suprahyoid structures and most of the hyoid. The wound was repaired within the first 6 hours in Korea. The scarring was minimal. The tissues were pliant. Muscle function was almost normal.

Figure 2 illustrates the early postoperative result of treatment for a severe avulsive wound of the middle face. The closure was complete. Face contour and muscle tone were maintained by treatment of the associated avulsive mandibular fractures. This treatment was also accomplished at a mobile surgical hospital in Korea.

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FIGURE 1. Successful early closure after avulsion of mandible and tongue, fourteenth post-wound day.

FIGURE 2. Successful early closure of avulsive wound of middle face with loss of right body of mandible, twelfth post-wound day.

Figure 3 shows a ROK soldier as received at an evacuation hospital. The wound appears to require extensive reconstructive surgery for repair and this most certainly would have been the case if early treatment had not been rendered. Actually, however, most of the tissues were not completely avulsed and could be returned to place and sutured. Figure 4 is the early postoperative result and figure 5 is the result in the sixth postoperative week.

Figure 6 illustrates a patient on the third post-wound day after evacuation to Japan. There was avulsion of the anterior and right body of the mandible and loss of considerable lip and chin tissue. Induration was marked. After 5 days preparation, the wound was closed over an acrylic dental splint which maintained the mandibular stumps in position and prevented undue distortion of the face following the closure. Figure 7 shows the postoperative result.

Figures 8 and 9 are the preoperative and postoperative illustrations of a severe middle-face wound closed in Japan. The early surgical

FIGURE 3. Middle-face injury, ROK soldier, first day of wound.

FIGURE 4. Same patient as figure 3, second postoperative day.

closures in these cases greatly modified the eventual reconstructive program.

Figure 10 shows a minor loss of deep tissue with extensive loss of superficial tissue. A skin graft was applied as soon as possible. Figure 11 illustrates the early result. Although the eventual program of repair was not materially altered by this early treatment, the patient benefited markedly by maintenance of muscle function through prevention of undue fibrosis. In addition, there were such secondary benefits as early return to a normal diet, reduction of the need for prolonged dressings and nursing care, shortened period of chemotherapy and the like.

In all such cases, the psychological benefits from early treatment are as striking as the functional benefits and should be further discussed. However, in this limited presentation, the consideration of the benefits of early treatment is closed with the statement that all who were primarily engaged in maxillofacial work in the Korean war be-

FIGURE 5. Same patient as figure 3, sixth postoperative week.

FIGURE 6. Unclosed wound, third day, with marked induration.

FIGURE 7. Same patient as figure 6, ninth postoperative day after closure over an acrylic splint.

came convinced that the time to begin definitive repair of such wounds is during the first few hours. For practical purposes, this is at the mobile surgical hospital level.

In considering how a higher percentage of patients in a future emergency might receive beneficial primary treatment, a large series of inadequately treated maxillofacial casualties in the Korean war was reviewed and the patients divided into six groups.

Group I

This group includes all those whose treatment was faulty or inadequate so that no material benefit resulted from the early treatment. Not all primary closures of wounds were successful. Of the repaired wounds involving the mouth, the breakdown rate was sufficiently high to cause some observers to question the advisability of early wound closure. However, these breakdowns almost invariably could be attributed to the failure to fully apply the principles of good surgery—

FIGURE 8. Unclosed wound of middle face, fifth day.

the principles that Colonel Soderberg has just discussed. A few points specially applicable to maxillofacial wound management are further presented here.

A. *Conservatism in Débridement.* Although stressed in all discussions of maxillofacial wounds, this point requires repetition with particular emphasis on conservatism in the management of bone fragments. Only rarely was soft tissue about a face wound observed to have been excised beyond the probable limits of devitalization, but mandibular fractures were frequently seen to have been stripped clean of small bone fragments. At a general hospital in Japan, there were many cases in which certain bone fragments, given little chance of survival, were deliberately retained because of their value in fracture management. Many such fragments survived (fig. 12) and the few sequestrations observed were not attended by particularly harmful sequelae.

B. *Tube Feeding.* In addition to maintaining a better nutritional balance in the presence of oral wounds, a diet based on tube feedings

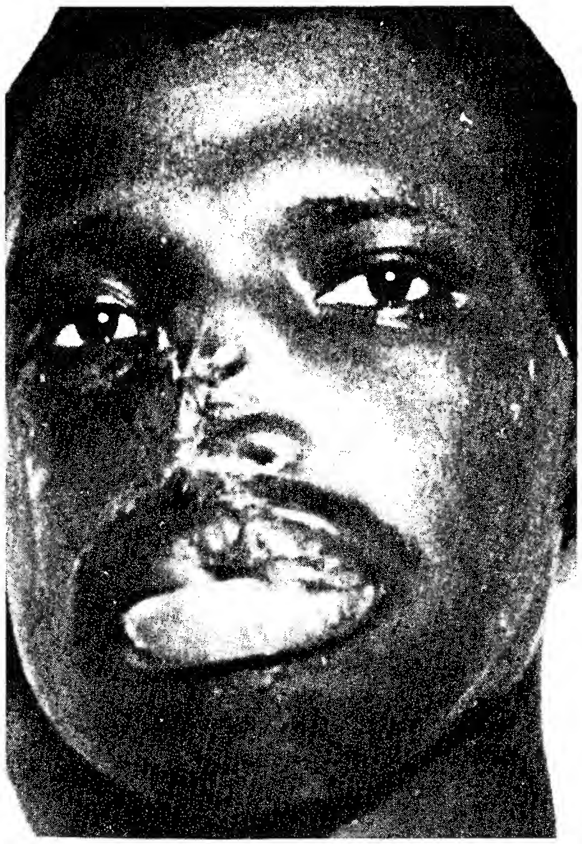

FIGURE 9. Same patient as figure 8, ninth postoperative day.

instead of diets by mouth as tolerated is of material local value in readying the wounds for closure and in shortening the postoperative healing periods. This is probably explained on a local basis of less salivation, better wound immobilization, absence of fermenting food debris in the wound, and better application and retention of compression bandages.

C. *Partial Closure of Indurated Wounds.* Most of these wounds requirement an operation for débridement. It was often found during this procedure that, although the wound might not be entirely closed because of inflammation or tissue loss, the tissue about minor oral penetrations or overlying exposed bone could be approximated without undue tension and would heal during the period of preparation of the entire wound for delayed closure. Thus a simple, superficial wound could be made of a complex one, speeding up the program of repair. For the patient in figure 10, the minor oral penetrations in the base of the wound were freshened, slightly undermined and lightly

FIGURE 10. Unrepaired wound, fourth day, with considerable loss of superficial tissue but minor loss of deep tissue and minimal penetration into mouth and mandible.

FIGURE 11. Sixteenth post-wound day, same patient as Figure 10, after early skin graft.

closed. The wound was then treated as a one-surface superficial wound while being readied for skin graft and an early graft could be applied with increased hope of success. Similarly, adjacent soft tissue could

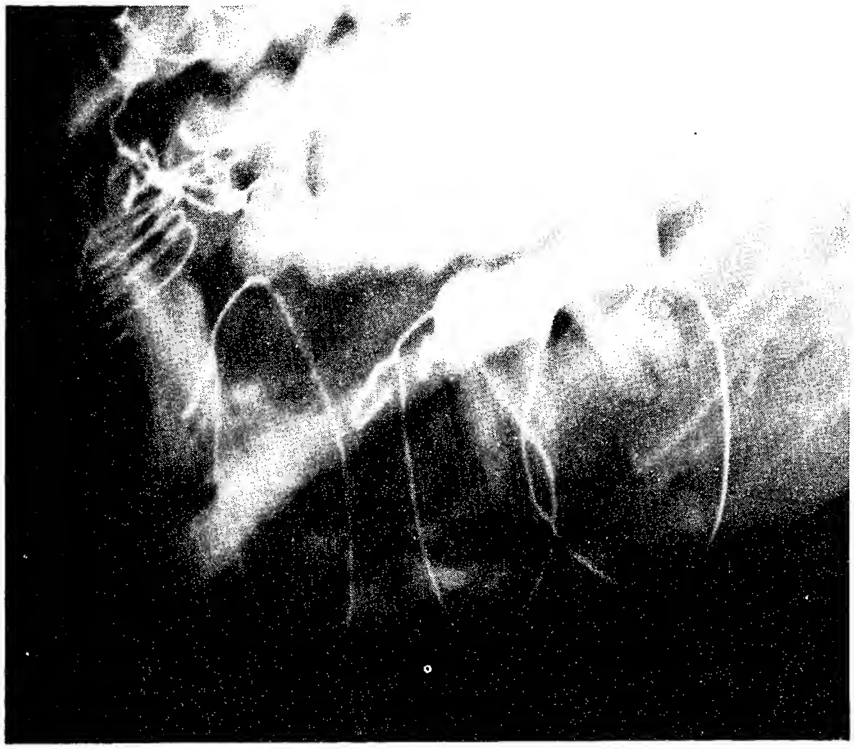

FIGURE 12. Severely comminuted fracture with deliberate retention of questionably vital bone fragments.

often be sutured over exposed bone during débridement and, if counter-drainage was established, the chance for bone survival was materially increased.

D. *Concomitant Treatment of Jaw Fractures.* Figure 13 illustrates a patient with extensive repair of soft tissue but with no definitive treatment of the associated mandibular fracture. The resulting depressed chin and elevated rami are typical of this type of injury. The lip is flaccid and there is drooling. Displaced bone fragments and adjacent soft tissues are now fixed. The facial and masticatory muscles have lost tone, partly from anatomical displacement and partly from suppression of voluntary function because of the pain associated with bone fragment movement.

If the bone is not generally aligned and moderately immobilized at the time of the wound closure, it cannot be secondarily treated during the critical period of fragment mobility without endangering the surgical repair during manipulation. Thus, the fracture should receive treatment prior to the soft tissue repair and, if this is to be quickly accomplished in the field, it is essential that the method of fracture

FIGURE 13. Soft tissue wound repaired without reduction of severely fractured mandible.

management be simple. One such method, adequate in most cases, is reviewed. Figure 14 illustrates a common type of missile fracture. Fragments are displaced from the main body of the bone and there are several fractures through the dental arch. A smooth rod about one-sixteenth inch in diameter, readily available in brass, steel or aluminum at ordnance repair shops, is cut and bent to approximately the shape of the dental arch. The ends of the rod are looped. The rod is then wired to the mandibular teeth beginning with the anterior fragment, and each fragment is slipped slightly along the rod to contact with adjacent fragments (fig. 15). The last tooth on each side is wired to the loops in the rod, anchoring the rod. The rod is then manually contoured until the result is a generally correct dental arch that will contact the maxillary teeth. Isolated fragments are incorporated into the reduction by passing circumferential wires over the occlusal surface of adjacent teeth, over the rod and about the fragments. Figure 16 shows immobilization completed by the application of intermaxil-

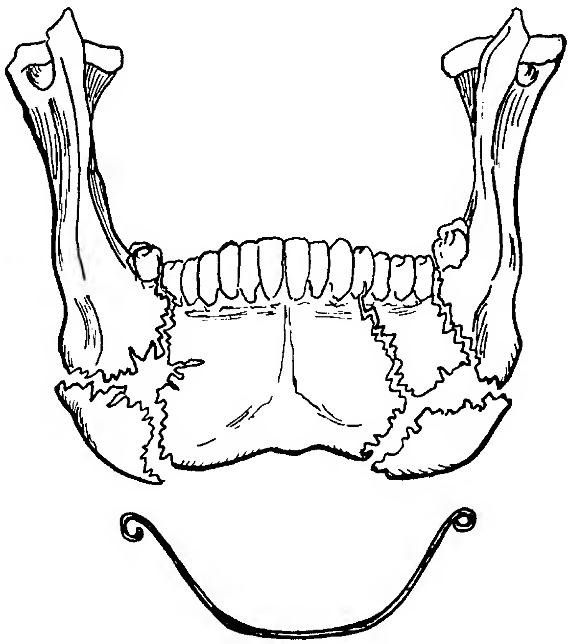

FIGURE 14. Typical missile fracture of mandible with $\frac{1}{16}$-inch metal rod adopted for reduction.

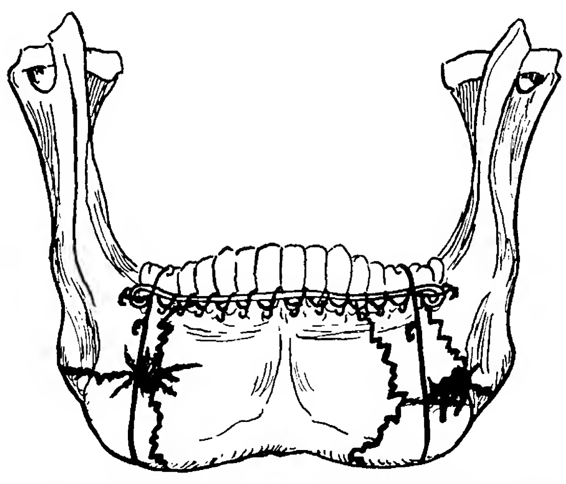

FIGURE 15. Metal rod wired to teeth. Isolated fragments incorporated by circumferential wire.

lary elastics between the wires holding the rod and wires applied in any of a variety of methods to the maxillary teeth. The small elastics may be cut from readily available latex surgical tubing. The number of elastics is reduced to two on each side during transportation, a

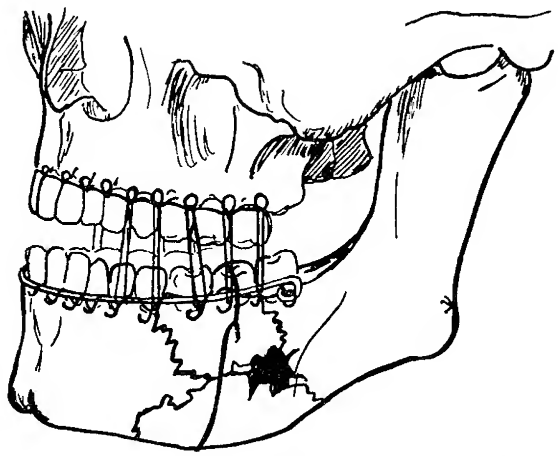

FIGURE 16. Immobilization completed by intermaxillary elastics to maxillary interdental wires.

traction sufficient to maintain comfortable occlusion without constituting a danger of asphyxiation in the event of hemorrhage or emesis.

At general hospitals, time and facilities usually permit construction of a splinting device during preparation of the wound for closure and the splint illustrated in figure 17 can be substituted for the metal rod. This splint is constructed only against the lingual surface of the dental arch and retained by steel wires looped about the cervices of the teeth and passed through holes constructed in the splint at the interproximal embrasures. It is superior to most splints in ease of insertion and adequacy of reduction and immobilization. It may also serve as a support for the closure of an associated soft tissue wound. Figure 18 illustrates a splint that bridges a gap caused by the primary avulsion of bone substance and will support the soft tissue following wound closure.

Occasionally, instances of overtreatment of fractures in the early stages were observed. Complex fracture gear often interferes with the surgical closure and precludes use of the important compression bandage. The blood supply to bone fragments, already markedly diminished, may be further impaired by excessive manipulation or intraosseous procedures in open reduction technics. Complex reduction and immobilization procedures can usually be safely deferred until the soft tissue wound has healed if the bone fragments are generally aligned and moderately immobilized by a simple device.

Many maxillofacial wounds can be managed by a general surgeon alone and others can be managed by a rhinolaryngologist or an oral surgeon, but usually combined efforts are indicated if the maximum in sound treatment is to be rendered. A more universal practice of

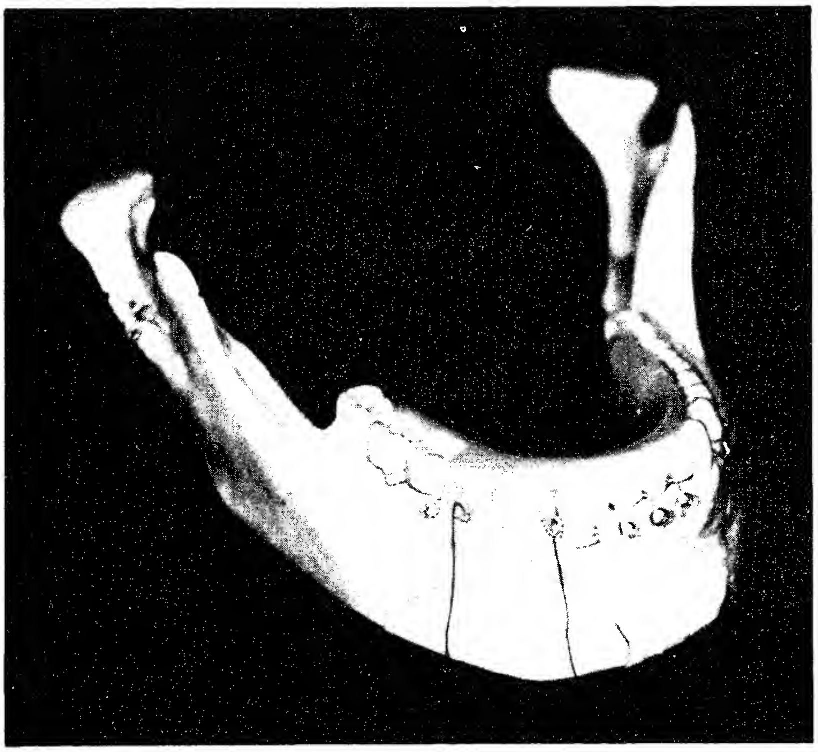

FIGURE 17. Acrylic splint constructed to lingual surface of dental arch and retained by interdental wires through holes in the splint.

this cooperation should result in a considerable reduction in the percentage of inadequacies of treatment. Dental officers were usually assigned to mobile surgical hospitals as Eighth Army policy but are not yet included in the official tables of organization. The inclusion of a dental officer should be made official and, whenever possible, the dentist should be a trained oral surgeon.

Group II

This group consists of patients whose wounds were severe and apparently so specialized in nature that, frequently, no early definitive treatment was attempted. Progress notes that accompanied such patients usually showed that the first receiving surgeons, after rendering essential life-saving and supportive care, had deliberately evacuated them without definitive treatment in the hope that they would shortly reach designated centers for specialized care. There were not enough such centers and evacuation was not sufficiently rapid to provide the indicated early treatment at the time that it could best be done.

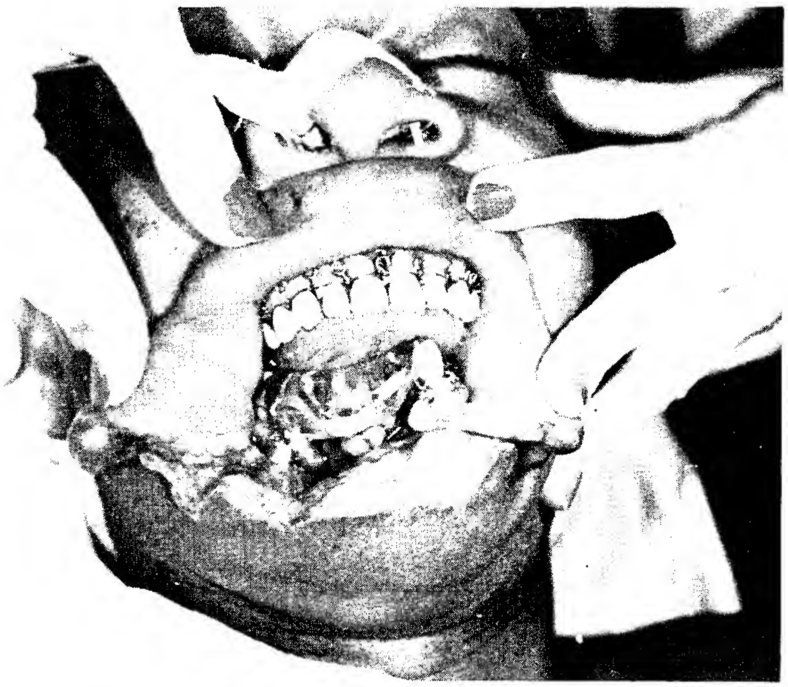

FIGURE 18. Acrylic splint, constructed to support the lower lip after closure and to immobilize mandibular stumps after avulsive fracture.

The best solution to this problem, if there were no limitations of personnel, would be to greatly expand the use of specialized teams at forward hospitals. A partial solution would be a more positive and publicized designation of rear area specialty centers but this also would require a positive program for priority evacuations. A third, and more practical, solution is to show all concerned personnel through educational programs that most of the essentials of early wound care such as débridement, closure of tissue over exposed bone with counter-drainage, fracture immobilization and adequate use of supporting bandage, need not await a specialist.

Group III

At the other extreme from those with severe injuries were those whose injuries were essentially superficial but so multiple as to require tedious, time-consuming procedures for repair. Frequently, such patients were not treated at forward installations because of the more apparent urgency for treatment of more seriously wounded patients. However, maxillofacial wounds, even when physically superficial, always have psychological and social implications that take them out of the category of insignificant injuries. Lacerations about

the lips that might readily be treated by cleansing and simple suture become contractures that require evacuation and complex plastic surgery after a few days healing. Dirt and debris blown through the skin that might initially be removed by a thorough sponging with detergents become "blast tattoos" that have kept many patients hospitalized in plastic centers for months. Figures 19 and 20 illustrate the probable prevention of a "tattoo" by cleansing a wound at an evacuation hospital in Korea shortly after the wound was incurred.

In addition to increased education as to the desirability of early management of maxillofacial injuries, the solution in this group also requires that adequate personnel be available at the forward hospitals. It is suggested that this personnel might be obtained in time of need from division dental personnel. There are 18 dental officers in the infantry division and their primary duties are materially altered when the division is in actual combat. The interests of the division

FIGURE 19. Markedly dirty wound of face.

FIGURE 20. Same as figure 19 after "tattoo" preventive cleanup and early repair.

might best be served if two or three of these dental officers were detached during periods of combat and assigned to the mobile surgical hospital in most direct support of that division. Even when they lack formal surgical training, such officers can be readily trained by the hospital's staff to be of material aid during periods of stress.

Group IV

This group consists of those with multiple wounds whose maxillofacial treatment was deferred primarily because of a more severe injury of head, chest, or the like. Occasionally, this deferment was actually dictated by the patient's physical condition but more often it was due to overspecialization of staffs or delays in routine consultatory procedures or the like. Again, increased education for the personnel concerned is the solution.

Group V

This group consists of those who received no definitive treatment because advanced personnel did not understand that such treatment was expected from them. It would seem that this group could be eliminated merely by the publication of directives or other minimal attempts at education, but such attempts have been misunderstood in the past.

As an example, an administrative letter from a higher headquarters is quoted in part:

> "*Maxillofacial Injuries*
>
> The principle that definitive treatment of patients with maxillofacial injuries should be provided as early as feasible is well established. A continuing problem exists in the delayed evacuation of these cases to specialized treatment centers. . . . Stations should evaluate cases promptly to determine that adequate treatment is within the capabilities of local personnel. . . . Evacuation actions should be expedited maximally."

This letter has been cited as being a directive against treatment except in specialty centers, an interpretation just the opposite from the letter's intent.

As a second example, an attempt was made in Japan to analyze the preventable causes of breakdown of repaired maxillofacial wounds and publicize this analysis in an effort to improve the results. Shortly, patients evacuated to Japan from a hospital which had previously accomplished excellent treatment began to arrive without definitive surgery. After inquiry, one of the surgeons concerned replied that he had heard the repairs were breaking down so he had stopped performing them. Again, this was an interpretation just the opposite from the one intended.

In late 1951, a brief course in oral surgery for dental officers from evacuation and mobile surgical hospitals was established at Tokyo Army Hospital. The result was an immediate improvement in the management of maxillofacial casualties, not because a great deal of oral surgery had been taught but because the officers attending the course were able to observe patients at both ends of the evacuation chain and learn specifically what was expected of them at forward hospitals.

Group VI

This last group consists of those who were evacuated without treatment because a critical military situation precluded any but emergency measures. Perhaps little can be done about this problem. However,

as in group III, the temporary assignment of two or three division dental officers to mobile surgical hospitals while the division is in combat would provide the hospital with additional personnel at a critical time.

Conclusion

The final result of treatment in maxillofacial wounds esthetically, functionally and psychologically, is largely dependent on the nature and degree of definitive treatment accomplished in the first few hours after the injury. Compared to the past, there was marked improvement in the management of such injuries in the Korean war but still further improvement can be attained.

After analysis of a series of untreated maxillofacial patients, it is seen that education of Medical Department personnel as to the essentiality of early treatment is the chief solution to the problem. One desirable method of instruction can be based on a policy of assigning replacement specialty personnel to advanced hospitals only after short periods of observation at rear area specialty centers in the evacuation chain.

The problem of the shortage of personnel at forward hospitals during periods of heavy casualties can be partially answered insofar as maxillofacial casualties are concerned by the temporary assignment of dental officers to the hospitals from combat divisions.

Acknowledgments

The patients illustrated in figures 1 and 2 were treated at the 8063 MASH by Dr. James R. Broun, Pendleton, Oregon. Figures 3, 4, 5, 19, and 20 illustrate patients treated at the 121st Evacuation Hospital and the illustrations were furnished by Captain Bruno W. Kwapis, DC. Dr. Marvin Cullen, Tampa, Florida, and Dr. Robert G. Canham, Chicago, Illinois, were associated with the writer in the management of the other casualties at Tokyo Army Hospital. The acrylic splint described in the text was first designed by Lieutenant Colonel James B. Neil, DC.

REPARATIVE SURGERY (SECONDARY SURGERY) IN THE KOREAN CAMPAIGN*

Colonel Frank E. Hagman, MC

The management of battle casualties during the Korean conflict, as in World War II, was in phases and conformed, in general, with military echelons and geographic deployment of military forces. This discussion will be limited almost entirely to certain aspects of reparative surgery which pertained to the Korean conflict.

The place reparative surgery had in combat may become clear from a brief examination of the four main phases in managing casualties. This concept was developed in World War II and used successfully in the recent conflict.

1. *Medical Aid Measures.* These measures were the first phase of management. They were administered within division areas and directed principally toward providing the most competent and urgent care in preparation for the second phase.
2. *Initial Wound Surgery.* This phase was performed usually in forward surgical hospitals. Initial wound surgery provided the first orderly and definitive surgical treatment of wounds. Under adverse combat conditions initial surgery necessarily was limited in scope.
3. *Reparative Surgery.* This phase, usually performed in Japan, continued surgical care to completion, beginning where initial surgery left off.
4. *Reconstructive Surgery.* This phase usually was accomplished in the Zone of Interior. It was the final stage of management for casualties with injuries of such magnitude as to preclude return to duty within the time limit set by the Far East Command.

During the Korean campaign reparative surgery was carried out largely in hospitals in Japan and as in World War II (*1*) had these objectives:

1. To shorten the period of wound healing.
2. To prevent and eradicate wound infection.
3. To restore function.

*Presented 23 April 1954, to the Course on Recent Advances in Medicine and Surgery, Army Medical Service Graduate School, Walter Reed Army Medical Center, Washington, D. C.

4. To return patients to duty.

5. As rapidly and safely as possible, to evacuate patients to the Zone of Interior when restoration to duty could not be expected within a reasonable time.

For the purpose of providing the best available care during the reparative phase of surgery, specialized treatment services in hospitals in Japan were organized for casualties inflicted with neurosurgical, thoracic, eye and cold injuries. In addition, efficient centers were provided for treatment of infectious hepatitis and for patients in the convalescence stage following injury or illness who required a period of reconditioning before return to duty.

The support given by personnel and hospitals in Japan to the management of battle casualties stemming from the Korean campaign was supremely and vitally important. On many occasions, because of the tactical situation in Korea, the first definitive surgical care was given in Japan. Moreover, the hospitals in Japan gave magnificient support to casualties with complications either overlooked in forward hospitals or developing inevitably during the patient's course.

Delayed Closure of Wounds

In the Korean campaign primary suture of war wounds in general was neither advocated nor practiced. Based upon experience of World War II (*2*), wounds were left open after initial surgery. Cranial, cerebral and maxillofacial wounds were exceptions to the policy as also were wounds associated with open injuries of the chest, with abdominal evisceration and with major joints. It soon became apparent that primary suture was unwise for the vast majority of casualties. Despite previous experience, primary suture was performed occasionally. Complications resulting from such practice occurred more often than necessary and were further convincing evidence against primary suture.

Delayed suture of war wounds, therefore, was necessary for most battle casualties subjected to initial surgery in Korea. Delayed closure of wounds constituted a large part of the reparative phase of surgery in Japan. It became a routine procedure, not very stimulating to surgeons interested in more exotic operations. Still it was of great importance to prevent undue cicatrization and production of granulation, obliterating anatomical layers; to prevent the hazards of cross-contamination from bacteria indigenous to the hospital and frequently resistant to available antibiotic and chemotherapeutic agents; and to hasten wound healing and lessen deformity and disability (*2*). Successful delayed closure in large measure depended

upon the interest of the surgeon (*3*) and painstaking attention to many details, among which were—

1. Period of nontransportability, during which casualties were not sent elsewhere. Immobilization of the region, surgically repaired, was frequently of prime importance.
2. Thorough débridement prior to closure. Well débrided wounds could be repaired early.
3. Repairing wounds within 4 to 6 days when possible, using appearance of wound rather than length of time as the governing factor.
4. Proper preparation of wounds not ready for repair.
5. Strict avoidance of tension for approximation of tissues.
6. Adequate drainage, preferably through a small separate stab wound.
7. Gentleness in handling tissues.
8. Fine suture material.
9. Culture and sensitivity studies of bacterial flora when failure occurred.

Secondary Hemorrhage

During the Korean campaign war wounds were often complicated by secondary hemorrhage (*4*) occurring on the average of 15 days after inception. Although hemorrhage was sometimes venous in origin, usually it ensued after arterial injury, more often associated with rupture of traumatic aneurysm than arteriovenous fistula and more apt to occur in infected than relatively clean wounds. Bleeding occurred unheralded, was alarming and even exsanguinating. Vascular injuries were overlooked at times and became apparent only when symptoms and signs pointed to the presence of traumatic aneurysm, arteriovenous fistula or when tempestuous hemorrhage suddenly supervened. Aneurysms and arteriovenous fistulae were managed conservatively when major vessels were involved and no serious or impending complications became apparent. It was the policy in the Far East Command to return such patients to the Zone of Interior. Operations were performed for indications such as the following:

1. Manifest internal or external hemorrhage.
2. Sudden increase in swelling or size of a lesion.
3. Sudden increase in pain when probably associated with vascular injury.
4. Imminent rupture of pulsating mass.
5. Increased swelling of extremity associated with a wound, with impaired circulation and probably not associated with phlebitis per se.

Surgical principles considered of importance were—

1. Adequate blood volume replacement.
2. Tourniquet control when possible.

3. Long properly placed incision.

4. Proximal and, when possible, distal control of artery before surgically attacking injured area.

5. Repair of injured artery when large and important, by suture of defect in its wall, by end-to-end anastomosis or by grafts if necessary (usually vein such as great saphenous).

Neurosurgical Casualties

The management of neurosurgical casualties during the early months of the conflict was a distressing problem, replete with difficulties. These difficulties stemmed from lack of sufficient neurosurgically trained personnel, inability to hold neurosurgical casualties in Korea, pressure of large numbers of other types of casualties, relative inexperience of general surgeons and the uncertainties pertaining to the Korean conflict. During the first months of the campaign, initial craniocerebral surgery was attempted in Korea and Japan by general surgeons. The incidence of complications such as acute and subacute cerebritis and frank brain abcess was reported to be 42 percent (*5*).

While a neurosurgical service was established in an Army Hospital in Japan soon after hostilities began, it was not until mid September 1950 that this service was headed by a board-certified neurosurgeon. Eventually Army neurosurgical casualties were sent to this service which was kept inordinately busy treating complications. It was not possible until February 1951 to place an Army neurosurgical team in Korea composed of partially neurosurgically trained medical officers under the supervision of the sole board-certified Army neurosurgeon assigned to the Far East Command. The reported incidence of craniocerebral complications gradually dropped to about 4 percent (*5*). In the meantime (and subsequently) a number of neurosurgical casualties were successfully treated by neurosurgeons assigned to U. S. Navy hospitals and hospital ships, including the Danish hospital ship "Jutlandia."

At least three experienced Army neurosurgeons could have been very usefully employed from the onset of the military effort. Should another conflict occur without warning, cognizance should be taken of this unfortunate experience of insufficient professional personnel for the management of neurosurgical casualties. It seems apparent that the military establishment should have within the regular corps or in reserve, neurosurgeons who could be depended upon to extend adequate support to the Armed Services much more quickly than was the case in Korea.

The volume of the reparative phase of craniocerebral surgery was reduced greatly by improvement of initial surgery. Some of the factors during initial surgery leading to improvement were—

1. Débridement of all layers of the scalp.
2. Excision, en bloc, of involved bone.
3. Débridement of dura.
4. Resection of all necrotic brain tissue.
5. Removal of all indriven bone fragments.
6. Closure of dura, by facial grafts if necessary.
7. Removal of metallic foreign bodies when feasible (including opposite side from missile entrance when close to cortex and associated with subdural hematoma).

Penetrating wounds of the spinal column and cord required débridement as completely as soft tissue wounds. Frequently wound care included laminectomy, removal of bone spicules, evacuation of hematoma and excision of devitalized tissue.

Prior to establishing neurosurgical teams in Korea much of this was done in Japan. Patients with paraplegia or quadriplegia were managed with infinite attention to details. Decubitus ulcer was extremely rare while these patients were overseas. These results were obtained by tireless, enthusiastic and sympathetic doctors, nurses and corpsmen. Patients were managed by periodic changes of position, employing the litter turning method or Stryker frame; by excellent nursing attention; by overcoming and preventing anemia; by maintaining and improving nutrition; and by employing catheter rather than suprapubic bladder drainage. They were transported to the Zone of Interior in pressurized cabin planes, on Stryker frames and under the supervision of trained personnel.

Thoracic Injuries

In the early days of the conflict patients with complicated thoracic injuries often were sent to the Zone of Interior because of insufficient hospital beds and personnel, circumstances beyond anyone's control at the time. Two Army thoracic surgical services were established and eventually were able to carry out reparative surgery. One service (*6*), for example, from the beginning of hostilities until November 1952 (16 months) gave the following support to battle casualties with visceral chest injuries:

Total patients treated	2, 577
Penetrating wounds	1, 855—72 percent.
Perforating wounds	670—26 percent.
Crushing injuries	52— 2 percent.
Patients with hemothorax	1, 598
Remaining bacteriologically sterile	1, 182—74 percent.
Infected	416—26 percent.
Chest clear after treatment	1, 262—79 percent.
Returned to duty	68 percent.
Evacuation to ZI with other injuries	32 percent.

During this interval 230 decortications were done on the service with the following results:

Infected	76 percent.
Noninfected	24 percent.
Good results—duty	91 percent.
Fair results—limited duty	4 percent.
Poor results—evacuated	5 percent.

The optimum time for decortication was found to be between 3 and 5 weeks. If attempted too early, bleeding, edema and difficulty in locating foreign bodies were noted. Ninty-two percent of patients requiring decortication had had closed intercostal tube drainage for hemothorax prior to being sent to this thoracic surgical service. While there were no doubt many other contributing factors, this sort of experience was used to intensify efforts in forward hospitals to treat hemopneumothorax by needle and syringe aspiration rather than by inserting intercostal tubes for drainage of hemothorax.

During this period foreign bodies were removed from the chest of 280 patients. These were classified as follows:

Shell fragments removed, 1–9 cm., mostly irregular	85 percent.
Bullets, various caliber	15 percent.
Mediastinal foreign bodies	77.
Pericarditis with effusion	34.
With abcesses	18.
Of heart muscle	14.

Operation for foreign bodies was employed for missiles 1.5 cm. in diameter or greater, when they were in a dangerous location or when they demonstrated persistent or developing reactions about them. Operation was delayed for 2 to 3 weeks to permit subsidence of local reaction about foreign bodies to lessen bleeding, facilitate locating and removing and to get patients in best possible condition.

Patients with thoraco-abdominal wounds were usually evacuated to the ZI because of complications associated with abdominal wounds. Chest injuries associated with neurosurgical injuries (271) were problems to manage and in paraplegics were aspirated and drained with difficulty because of position. Patients with associated orthopedic injuries (602) in the majority of instances required evacuation to the Zone of Interior.

It is of more than passing interest that the overall mortality for patients on this service during the period of this report was 0.5 percent and the surgical mortality was zero.

Maxillofacial Wounds

Reparative surgery of maxillofacial wounds was done usually by teams comprised of a general surgeon, interested in and familiar with

the head and neck, a dental surgeon experienced in this field, an experienced anesthesiologist or anesthetist capable of giving nasotracheal, orotracheal or transbronchial anesthesia, and competent nurses and corpsmen (7). Nasogastric intubation was employed for feeding patients when swallowing was difficult and for patients troubled with vomiting.

Wounds extending into the mouth frequently disrupted, especially when buccal mucosa was not sutured initially and when good mouth hygiene was neglected. Gross infection and necrosis were treated by irrigation, antibiotics, removal of foreign bodies and loose bone spicules and loose and broken teeth.

Fine absorbable everting mattress sutures were employed within the mouth to close the buccal cavity and cover bone. Dependent drainage was provided. Covering was furnished for avulsed jaws, lips and mucosa. Fractures were treated by fixation employing intra-oral wiring or extra-oral fixation. Postoperative irrigations were employed every 2 hours or oftener and after intake of food. Tracheotomy was done, if not done previously, for extensive injuries of the tongue, larynx and neck, or when hemorrhage, infection or edema threatened embarrassment of the air passages. Injuries of the parotid duct were repaired over a ureteral catheter employing 5–0 silk sutures. Mucoperiosteal flaps were provided for injuries involving the hard palate.

Patients requiring extensive reconstructive maxillofacial surgery were returned to the Zone of Interior. Important principles of maxillofacial repair included—

1. Frequent saline irrigations.
2. Large doses of antibiotics.
3. Early débridement.
4. Conservation of skin and bone.
5. Removal of loose teeth and bone spicules.
6. Early closure of mucous membrane.
7. Dependent drainage.
8. Fixation of fractures.
9. Postoperative irrigations.
10. Tracheotomy as indicated.
11. Teamwork.

Abdominal Wounds

Experience in Korea did not change concepts of managing wounds of the large intestines as promulgated during World War II. Most surgeons practiced exteriorization of large bowel injuries through a

separate muscle-splitting incision. Occasionally an individual surgeon failed to follow this general practice, closed colonic wounds primarily and dropped the colon back into the abdomen. In some patients nothing untoward happened. However, too many patients so treated developed abscess, fecal fistula and increased disability to warrant primary closure despite liberal use of whole blood, antibiotics, etc.

The difficulty with exteriorization stemmed, first, from employing laparotomy wounds rather than separate muscle-splitting incisions, and second, from inadequate mobilization of the bowel at the time of exteriorization (or defunctioning colostomy). The former increased severe infection while the latter resulted in retraction of the colon in whole or in part back into the abdomen. In either event the resulting difficulties provided clinical material for surgeons in Japan, complications preventable in whole or in part at the time of initial surgery. Furthermore, rectal injuries which had escaped recognition initially presented problems such as fecal fistula, abscess and retroperitoneal cellulitis. Aside from revising and instituting colostomies, surgeons were able to close many colostomies and return patients to duty within the theater.

Efforts were directed towards repairing fistulae of the small bowel early to prevent further depletion of nutrition, water and electrolyte balance and when closure was impracticable to short-circuit around them to accomplish the same purpose. The many and various complications involving wounds of the abdomen were treated in accordance with sound surgical principles supported by all available adjuvants.

Extremities

The basic concepts derived from World War II for managing injuries of the extremities were employed. These included an adequate period of nontransportability for the casualty to provide balanced suspension and traction for reduction and alignment of fractures until union occurred, early closure of wounds, additional débridement as necessary, careful attention to nutritional and blood deficiencies and administration of appropriate antibiotics.

Evacuation of patients to the Zone of Interior with open fractures of major bones had to be done early during periods of acute shortage of facilities in Japan (*8*). When patients could be returned within 2 weeks after wounding this practice was reported by orthopedic surgeons in the Zone of Interior, who subsequently received and treated them, to have certain advantages:

1. Less beds were required overseas.

2. Patients were received early enough for definitive treatment and required no further movement until completely rehabilitated.

3. Slight delay did not materially increase wound infection, impair the results of wound closure, decrease function or increase disability.

4. But there must have been absence of complications and contraindications, and transportation must have been completed within the 2-week period.

Interamedullary fixation (*9*) of long bones was usually reserved for closed fractures and therefore was not employed extensively in battle casualties. However, occasionally the method was used when débridement had been satisfactory, permitting early closure of soft tissues, and it appeared reasonably certain that the patient could be sent to duty within the theater.

Convalescence Hospitals

It is abundantly clear that the foregoing discussion has dealt with only a few highlights of reparative surgery. Before concluding, a few remarks concerning hospitals for convalescence and rehabilitation should be made. Separate organizations were provided without elaborate treatment machinery. These units carried out dynamic, efficient, complete, and uniform programs to fill the devitalizing hiatus which existed after patients required no further definitive care but still were not fit for return to duty.

Convalescence hospitals in Japan served with great distinction and furnished brilliant backing for other hospitals during the final phase of medical care. The approach to patients was positive (*10*), aimed at rapid restoration of function and resumption of normal physical activities. Patients soon began to look and act like soldiers.

Many ambulatory neuropsychiatric patients were sent to convalescence hospitals direct from Korea. Under the supervision and care of psychiatrists they participated in the reconditioning program.

All patients were placed in one of four classes in accordance with their physical condition after evaluation by medical officers in attendance. As rapidly as possible patients were placed into the next more active class and finally discharged to duty.

Patients were organized into military units, lived in barracks, complied with demands of military discipline and alternated physical activities with classroom work. At all times the environment of convalescence hospitals was such that patients were encouraged to shed spurious gains of chronic invalidism for resumption of adult obligations of normal human beings.

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